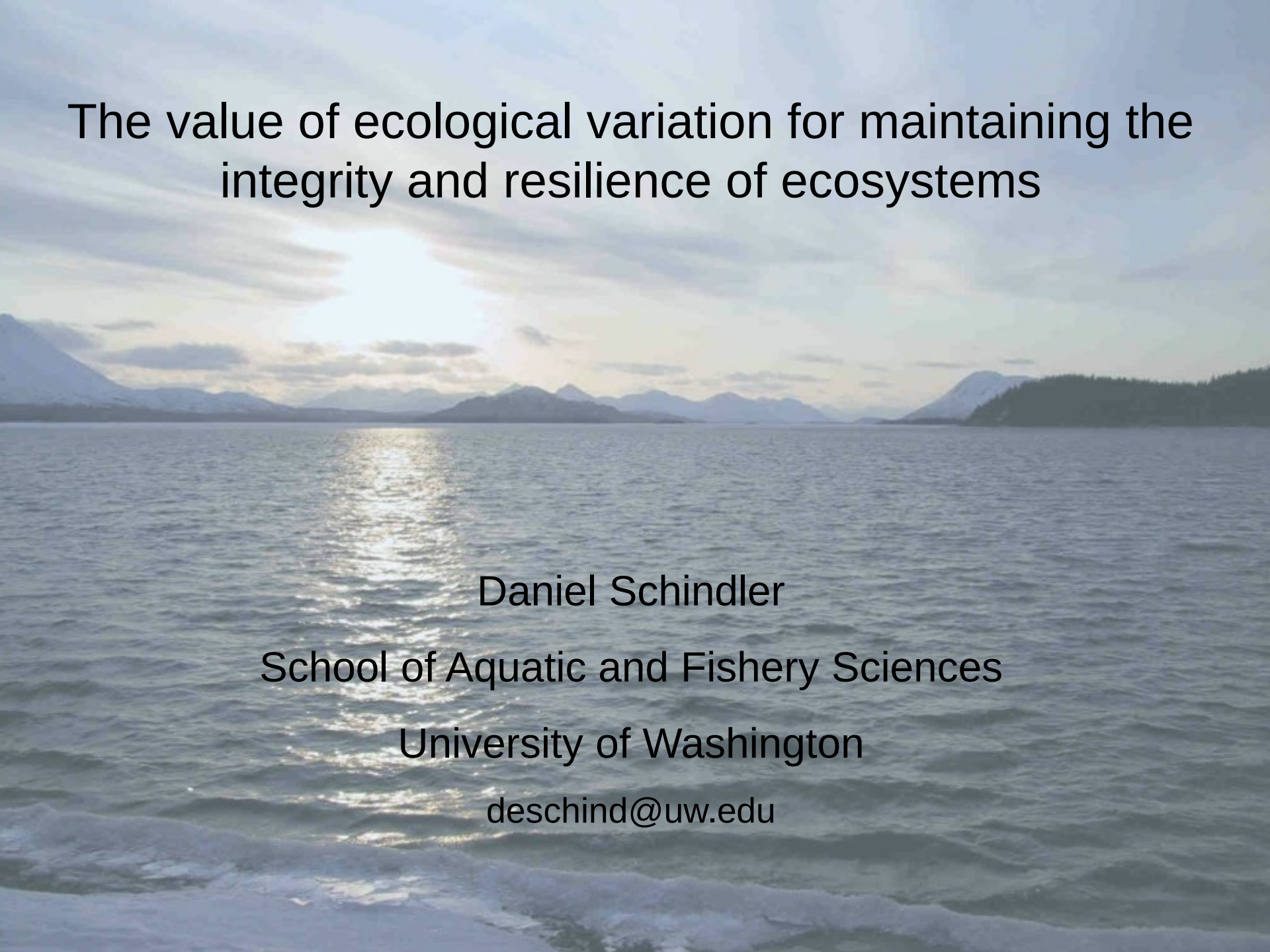
The value of ecological variation for maintaining the integrity and resilience of ecosystems



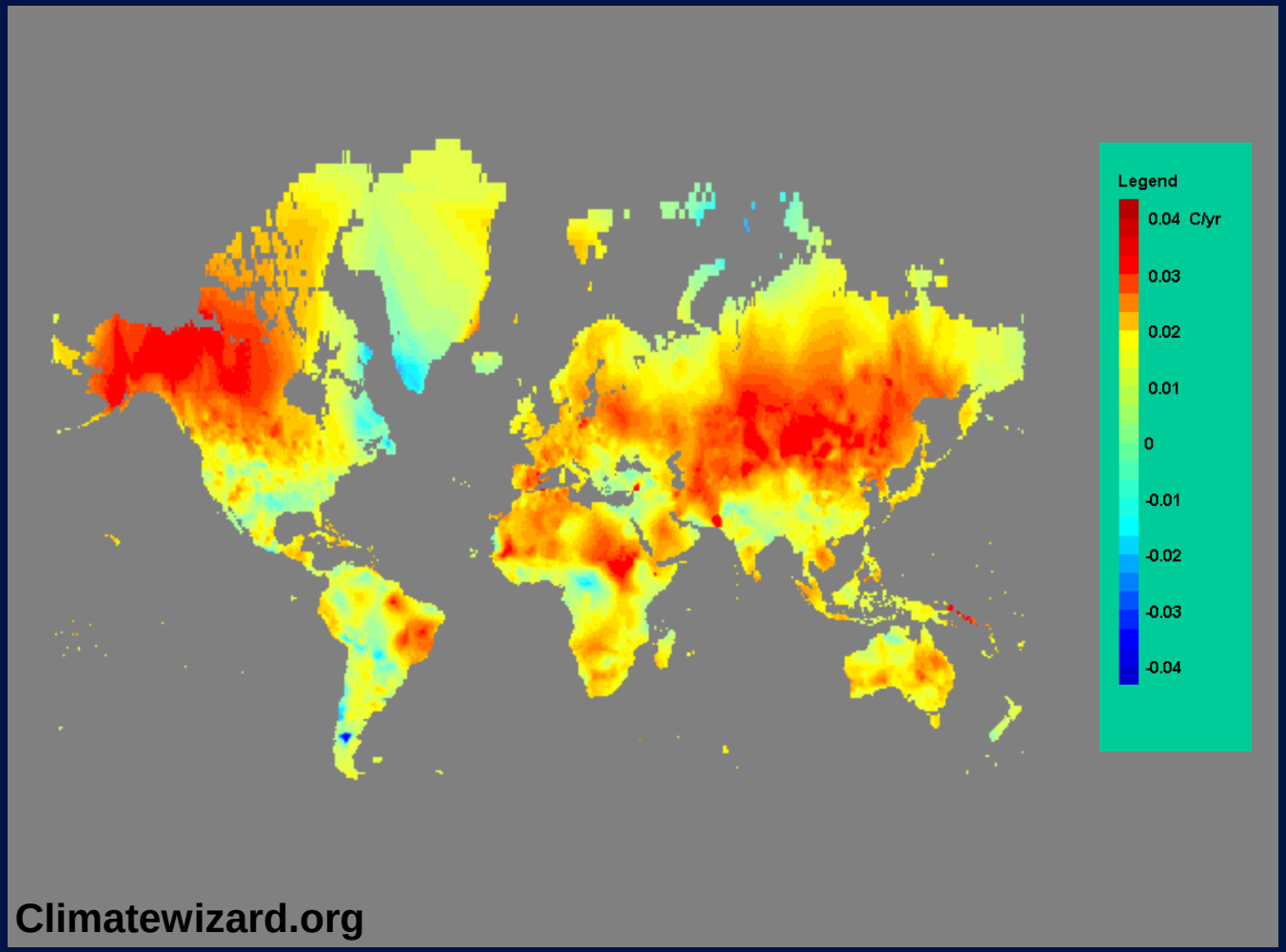
Daniel Schindler

School of Aquatic and Fishery Sciences

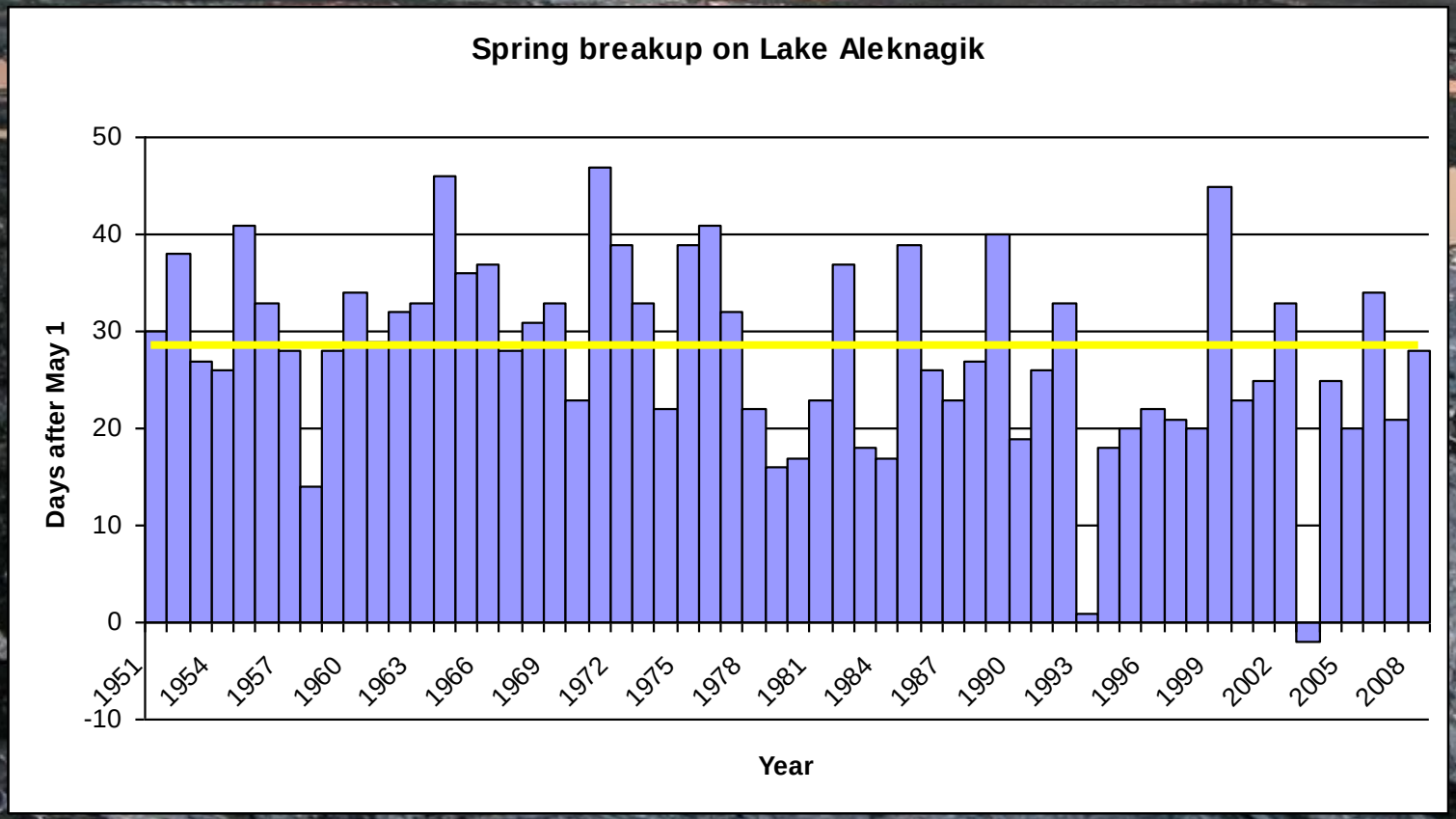
University of Washington

deschind@uw.edu

Global warming since 1950



Changing climate in Western Alaska



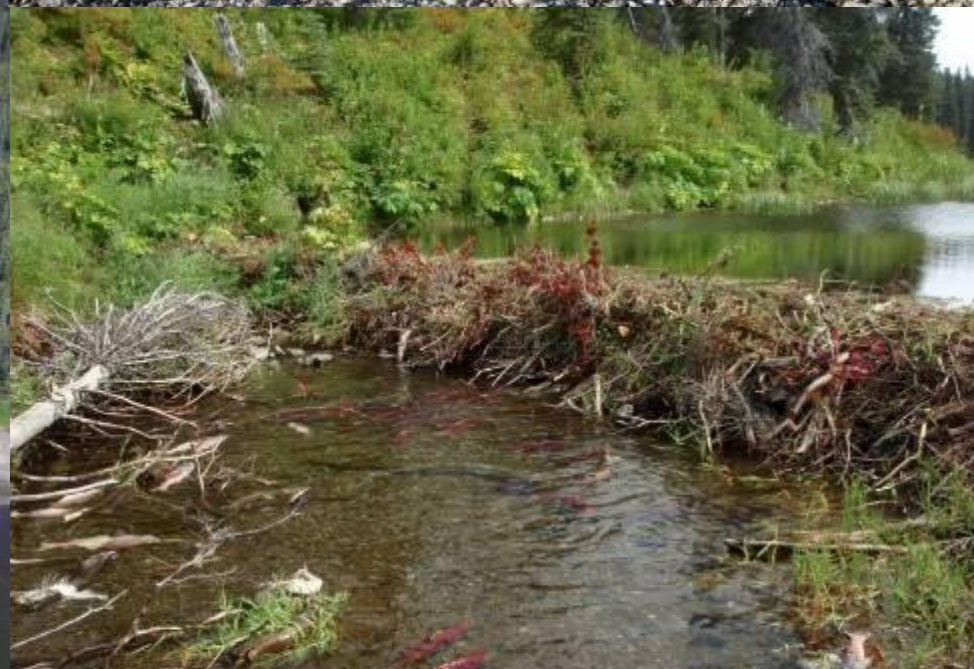
Bristol Bay, Alaska

Sockeye salmon have different biological features, depending on the habitat they occupy

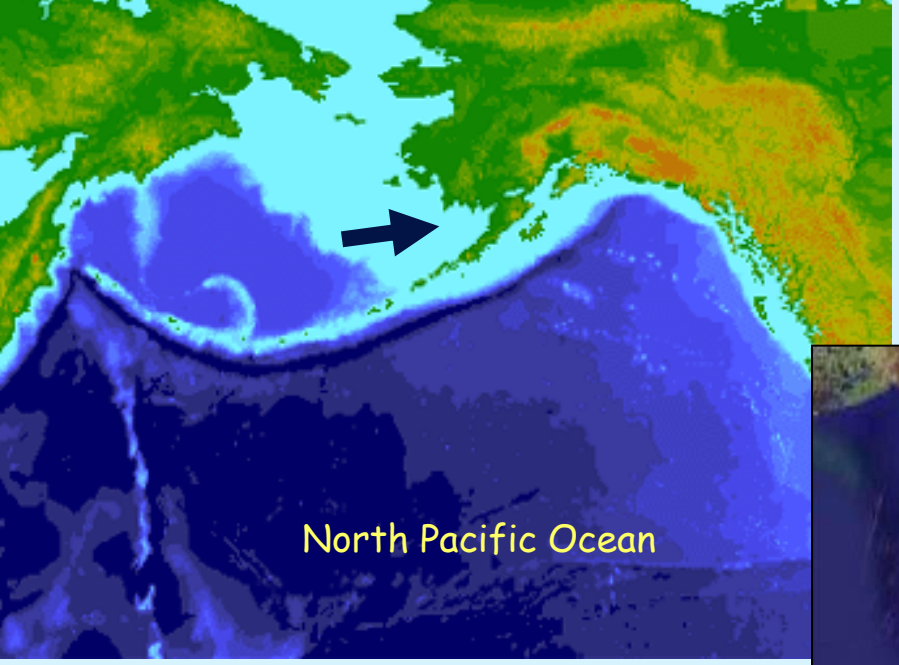
Lake beaches

Small streams

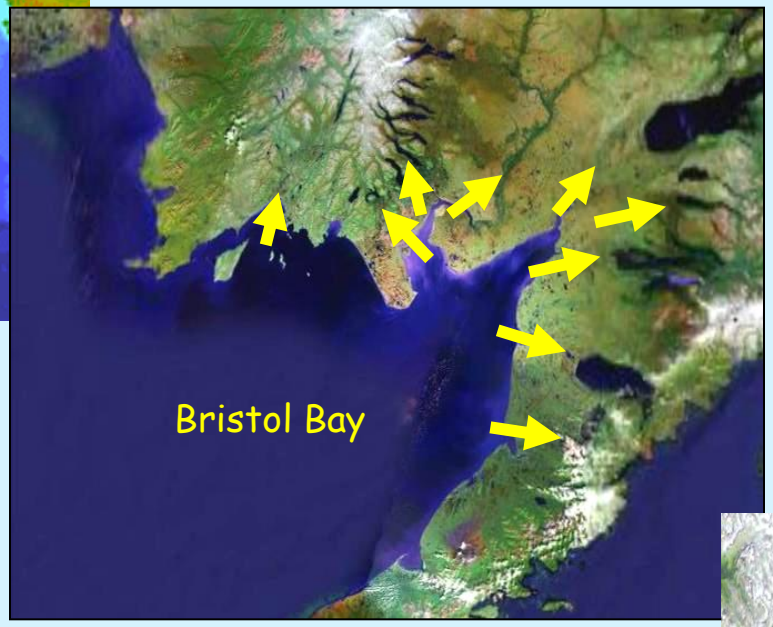
Salmon landscapes are shifting mosaics of suitable habitat



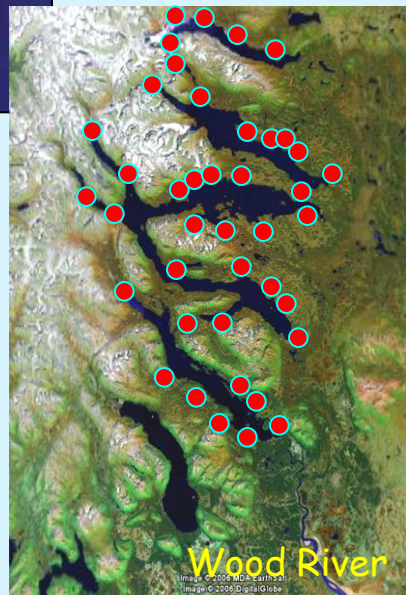
Salmon habitat in Bristol Bay



9 major rivers

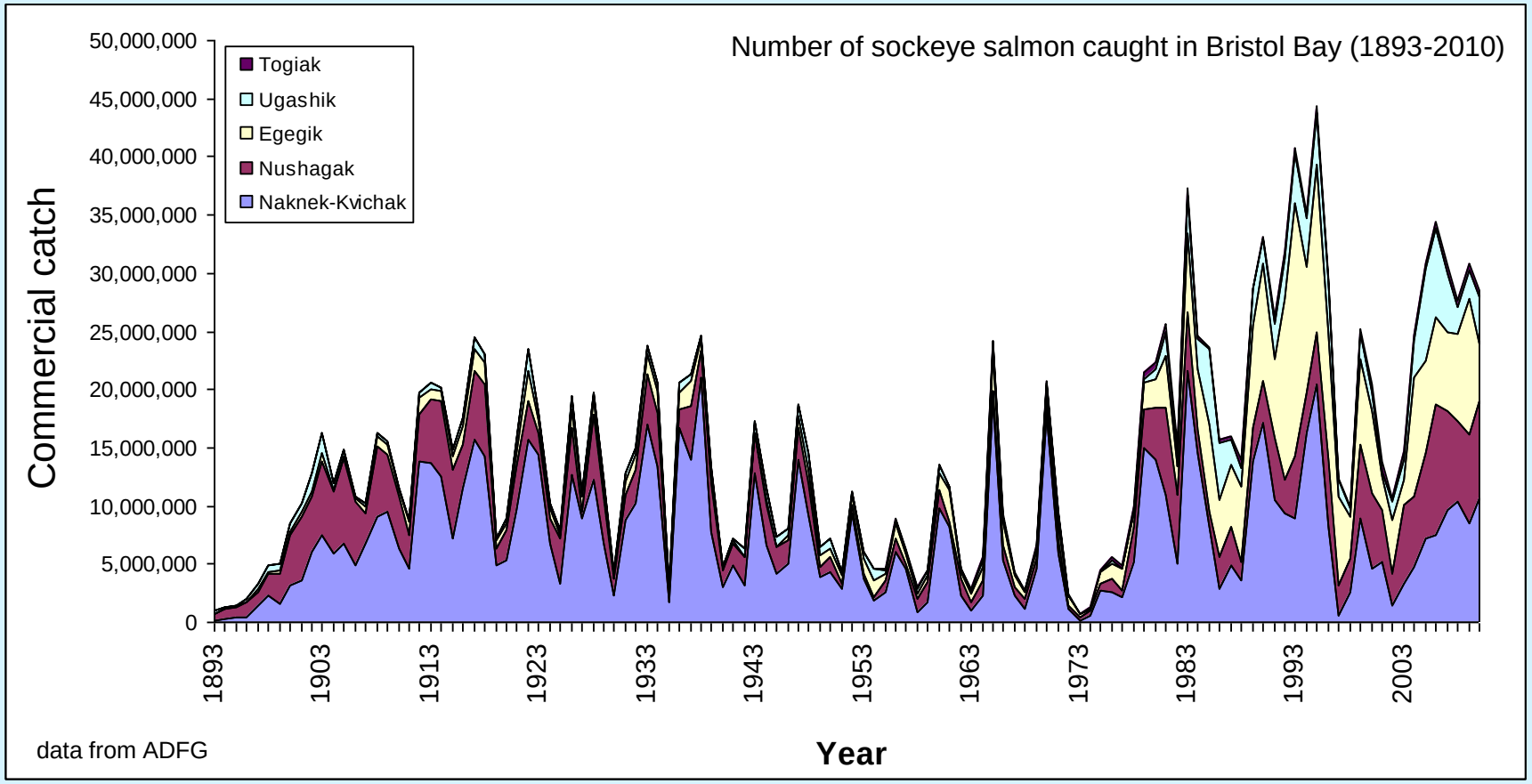


each with many populations

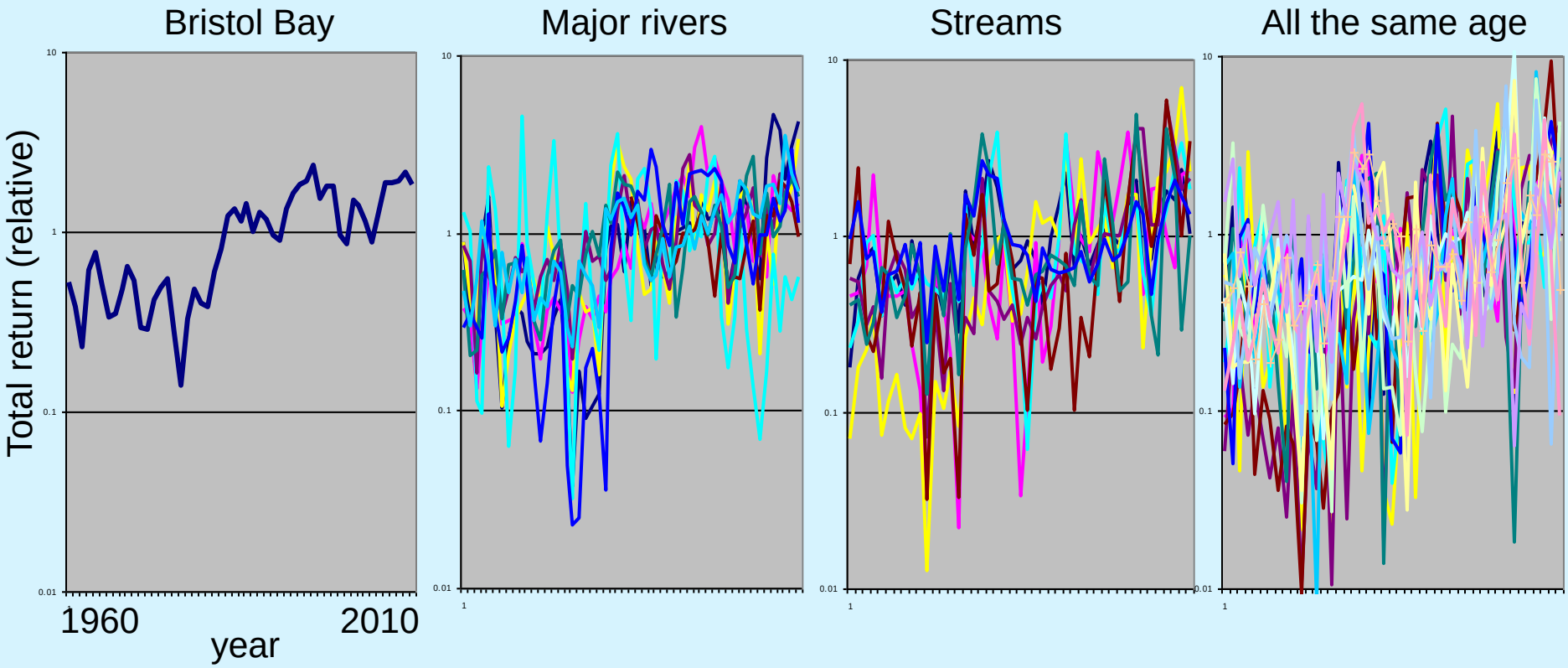


Commercial fisheries for sockeye salmon in Bristol Bay have been sustained for over 120 years

- record catches have occurred within the last 20 years -



Salmon returns to Bristol Bay are two times more reliable than the individual components of the portfolio



Reliability affects people dependent on fisheries

http://www.absc.usgs.gov/research/Fisheries/Lake_Clark/subsistence.htm

The front line at Egegik

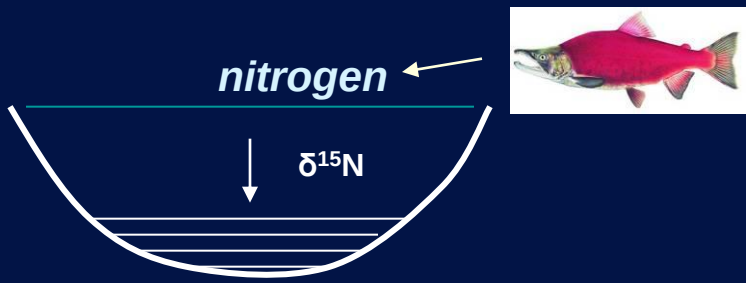

Sue Johnson

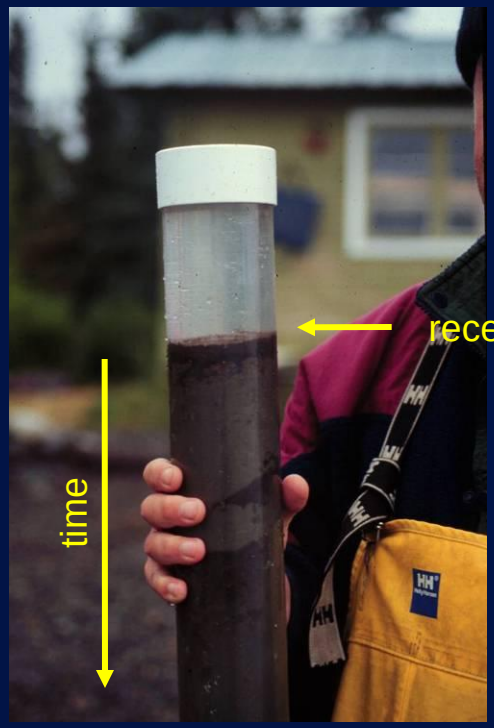

Jonny Armstrong

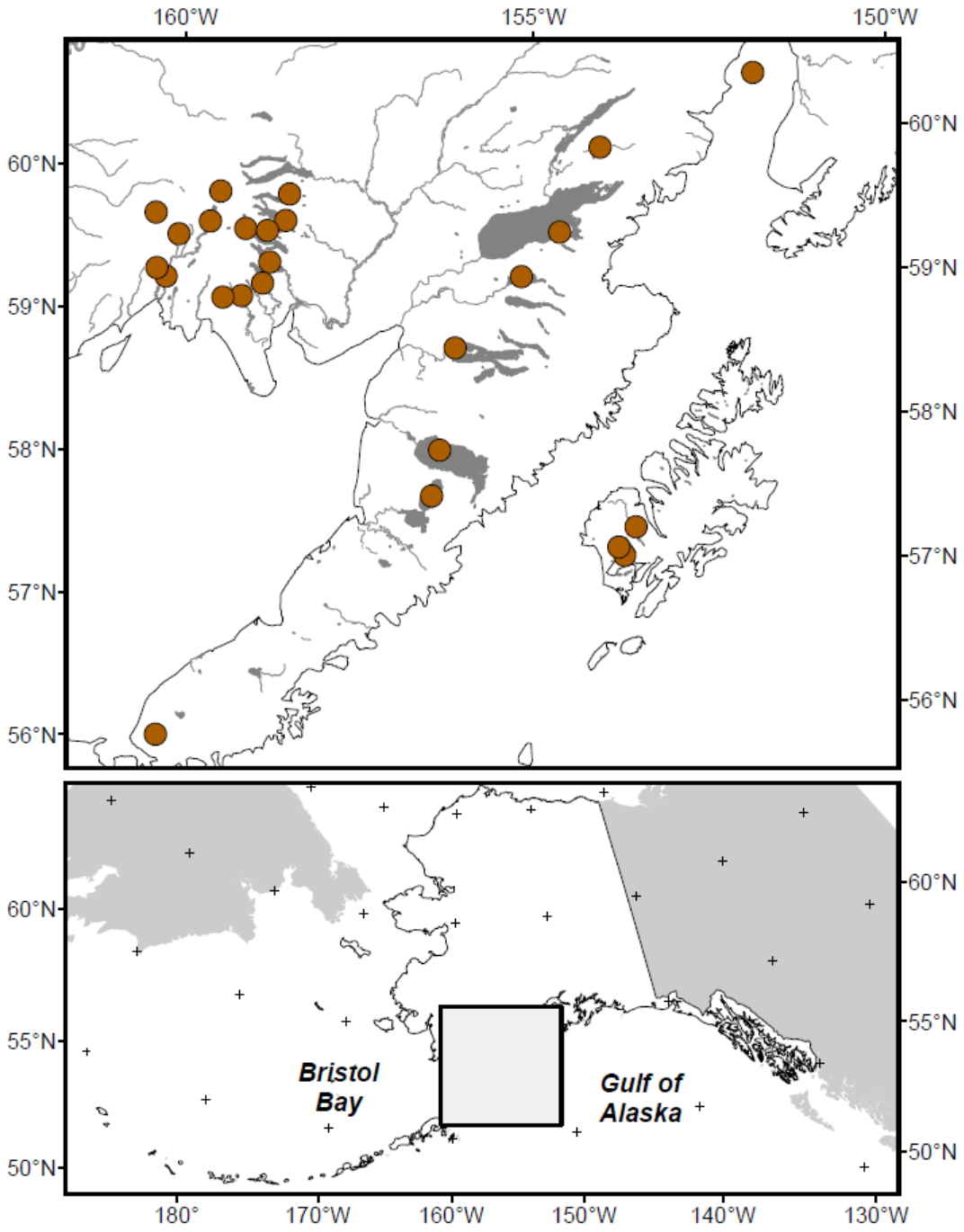

Does diversity play out over longer time scales (centuries)?

Paleolimnology

Lake sediments contain a biogeochemical archive that reflects salmon abundance

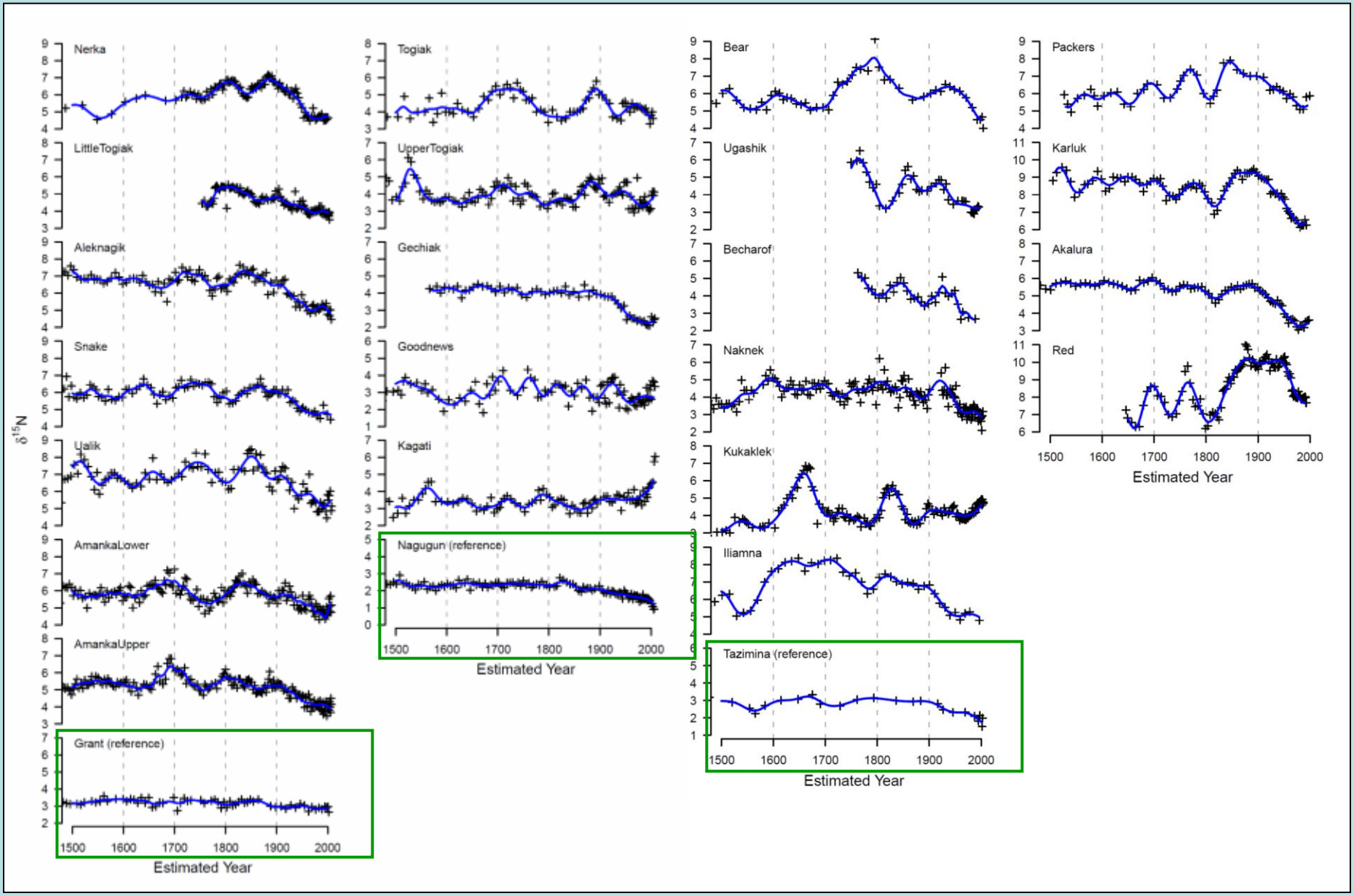






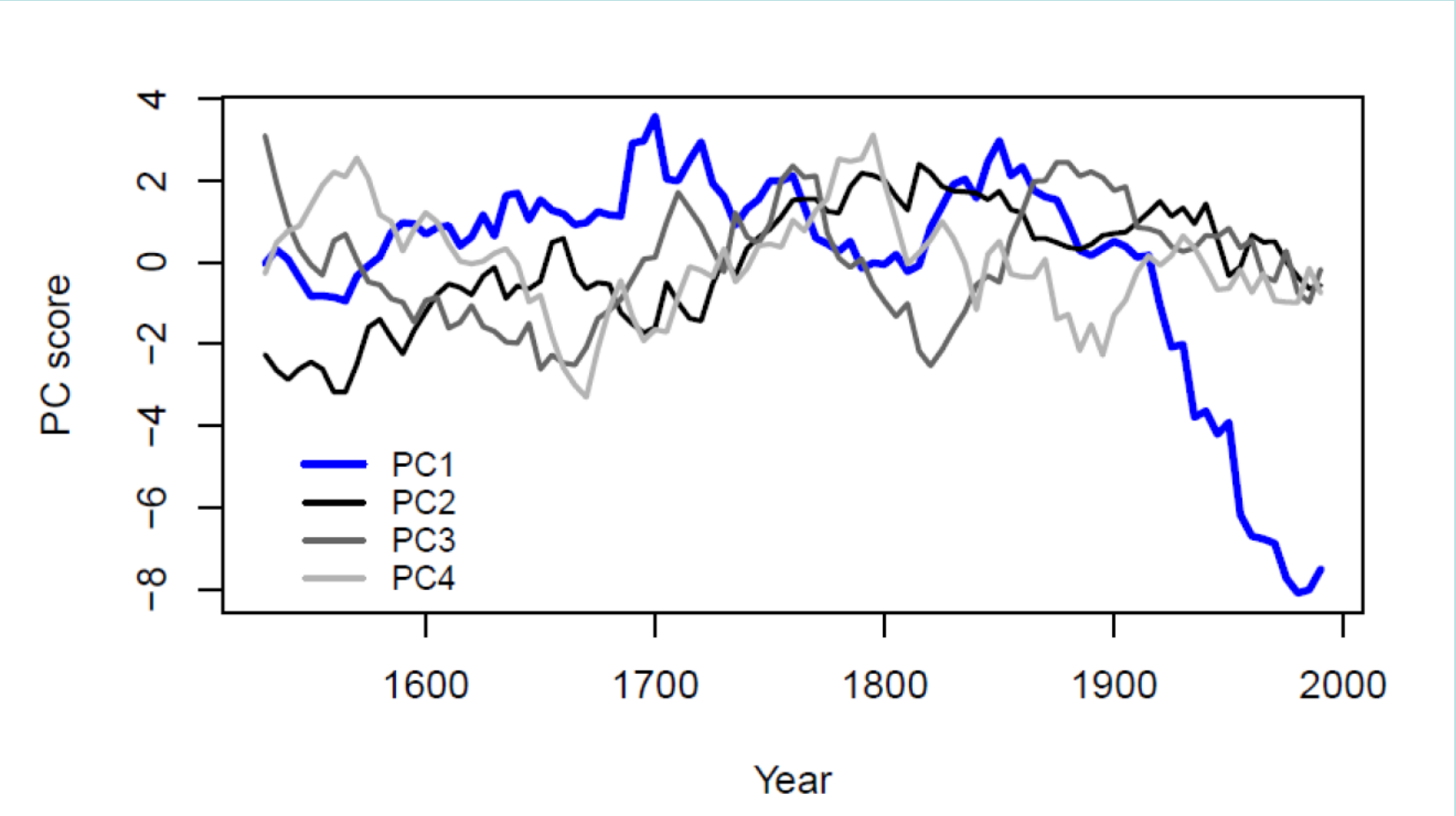
Daniel Schindler
Peter Lisi
Gordon Holtgrieve
Lauren Rogers
Peter Leavitt
Lynda Bunting
Pat Walsh
Mark Lisac
Bruce Finney
Irene Gregory-Eaves

Variation in salmon returns to Alaskan lakes 1500-2000

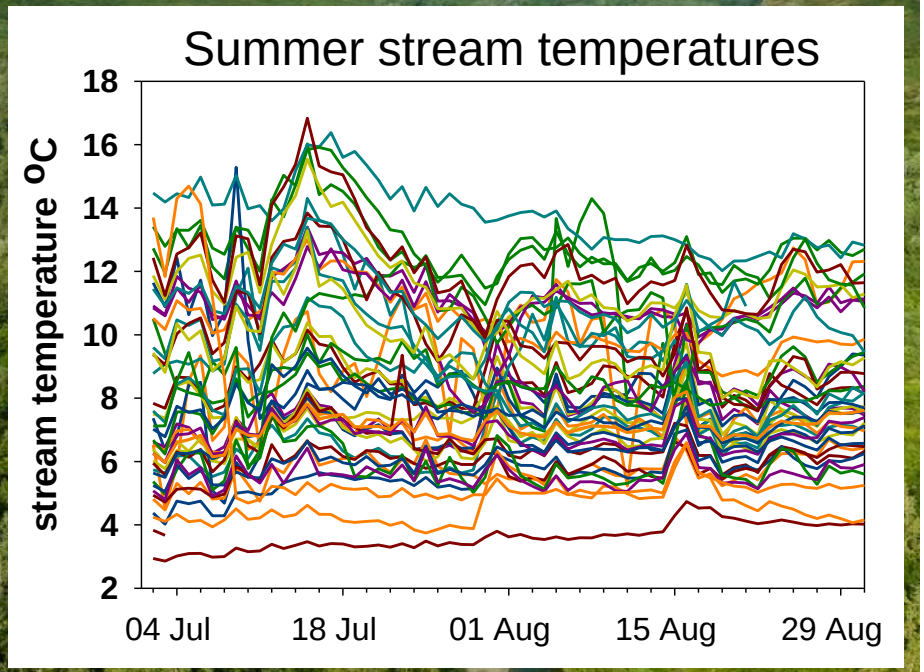


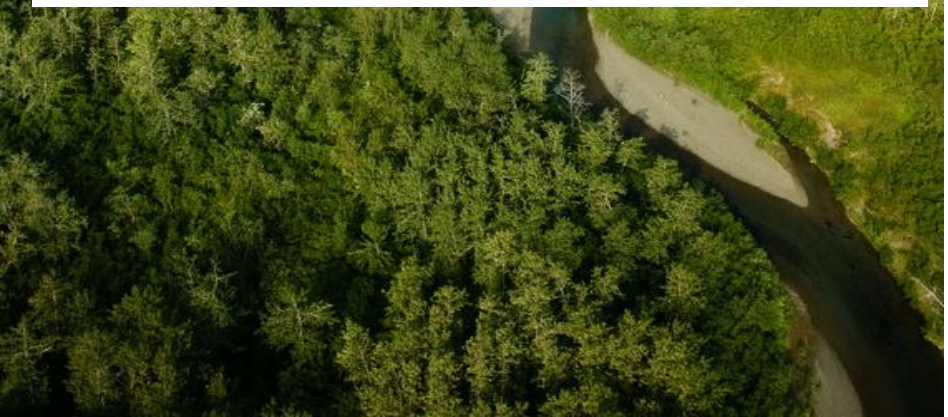
Rogers et al., in prep

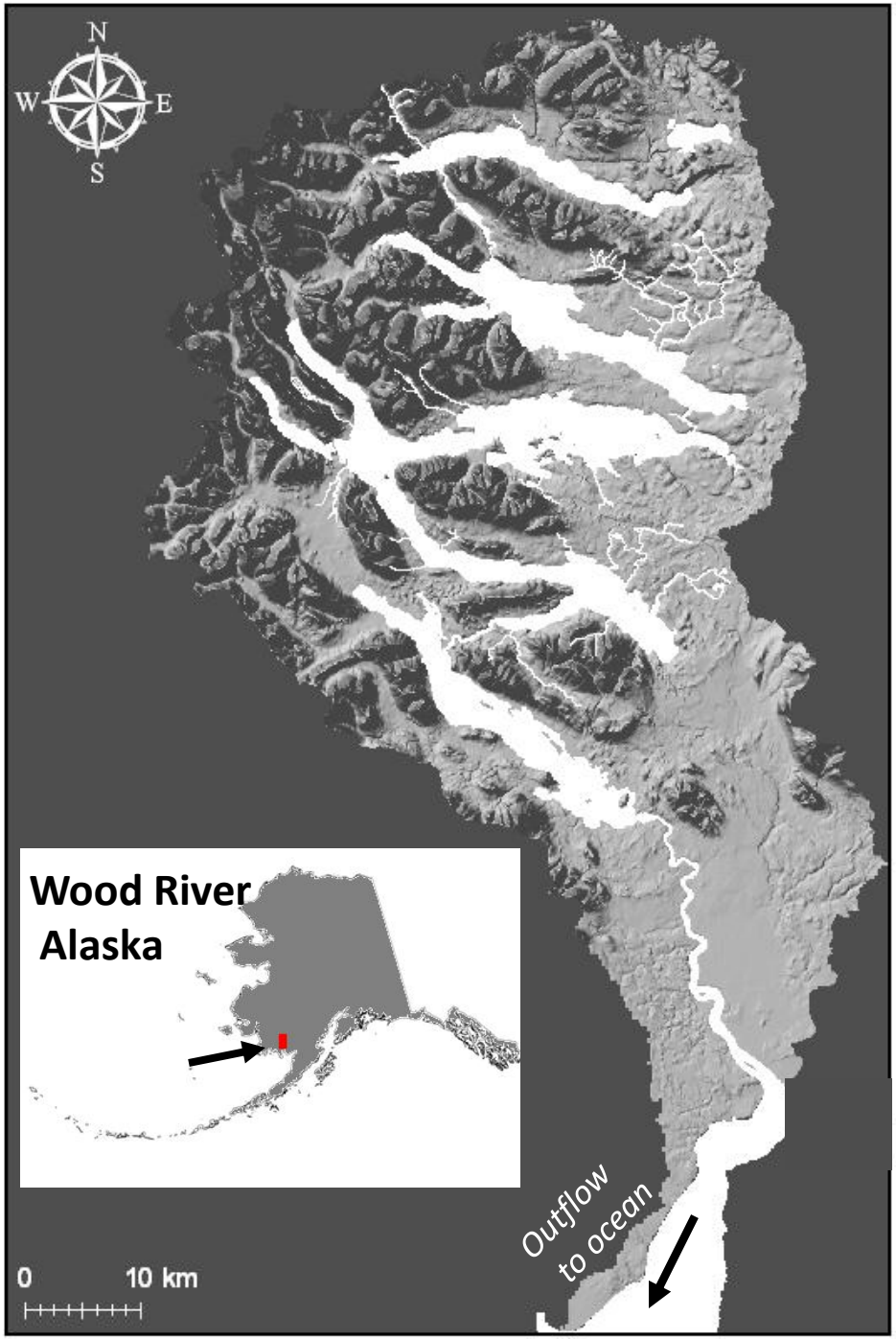
Weak coherence in salmon population dynamics among stocks in western Alaska (1500-present)



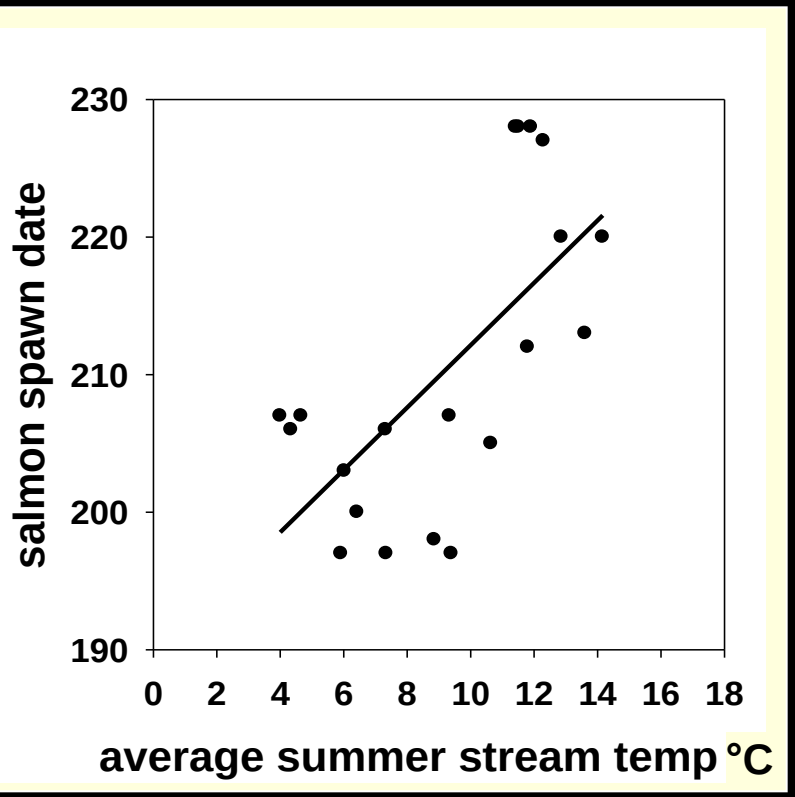
Lauren Rogers


Summer stream temperatures
stream temperature °C
18
16
14
12
10
8
6
4
2
04 Jul
18 Jul
01 Aug
15 Aug
29 Aug

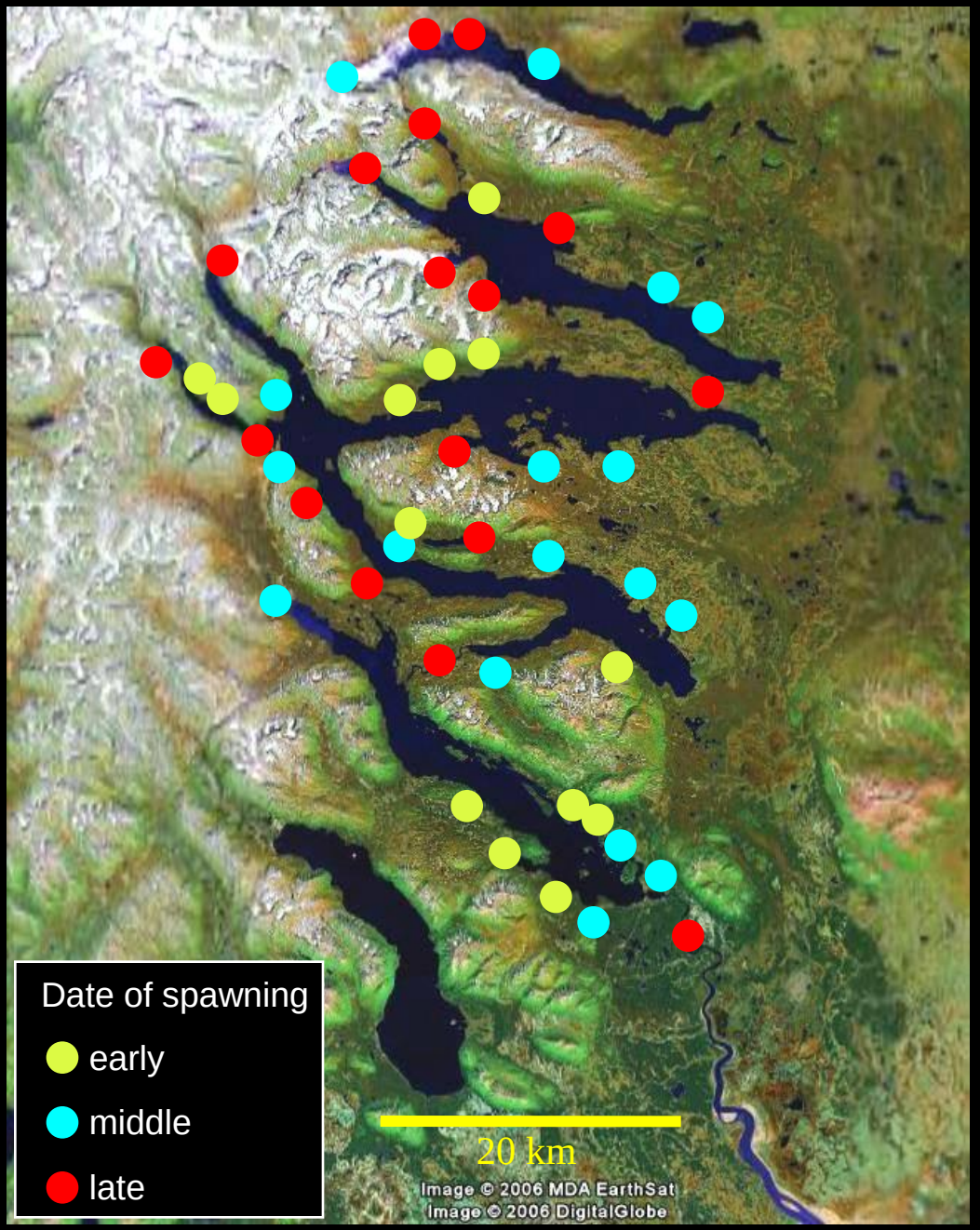



N
W
E
S
Wood River
Alaska
Outflow
to ocean
0
10 km

Watershed scale



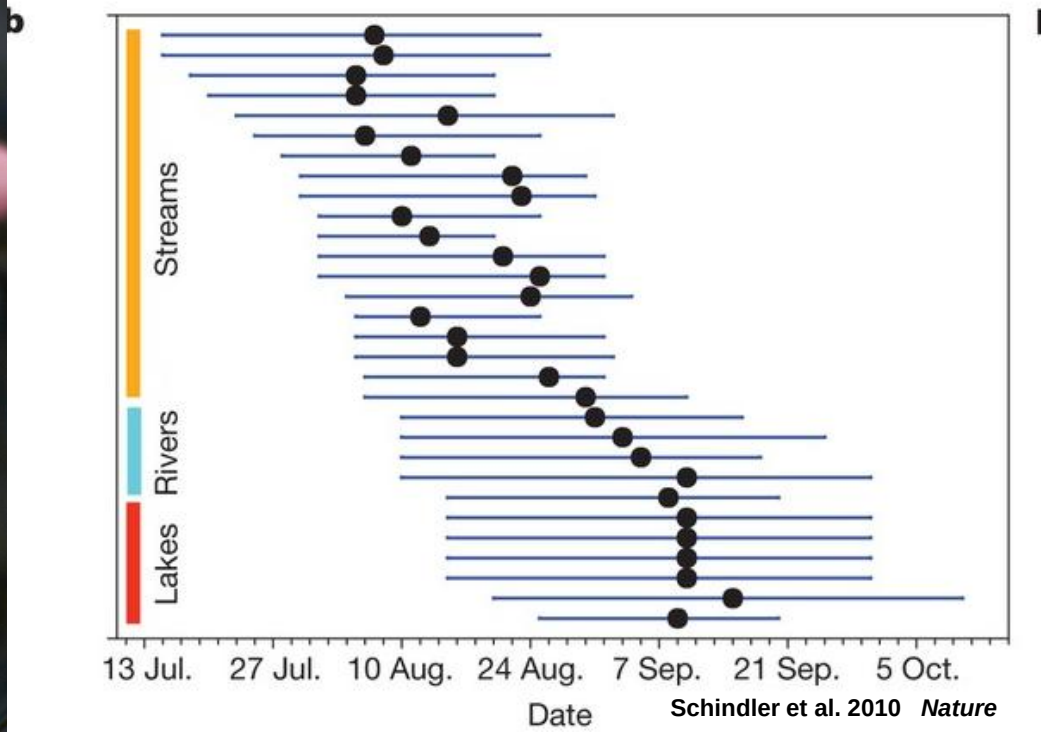
Peter Lisi *in prep*



Analogous terrestrial systems:
Fryxell et al. 2005 *Ecology Letters*
Wang et al. 2006 *Ecology*
Sawyer & Kauffman 2011 *J. Anim. Ecol.*

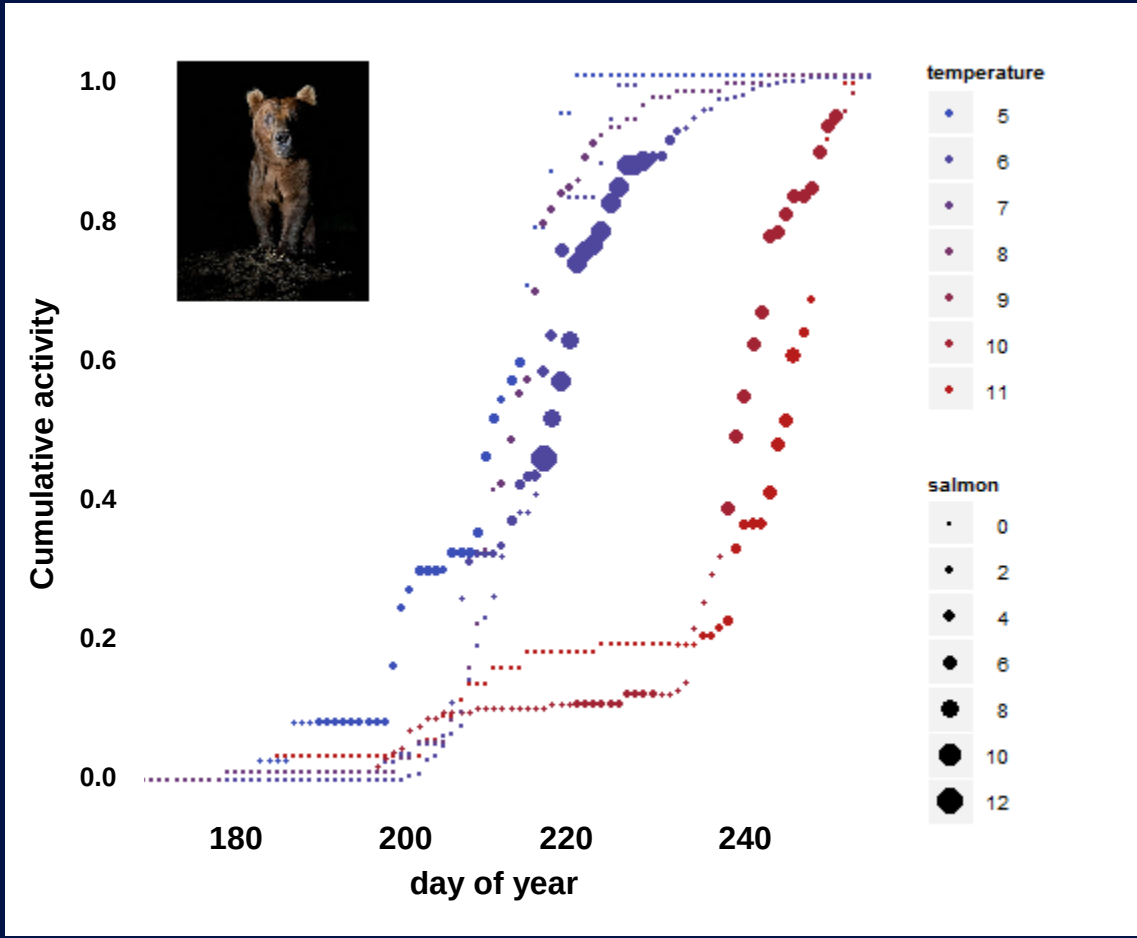
Photos by J. Armstrong

Ruff et al. 2011 *Ecology,* K. Bentley *in prep*

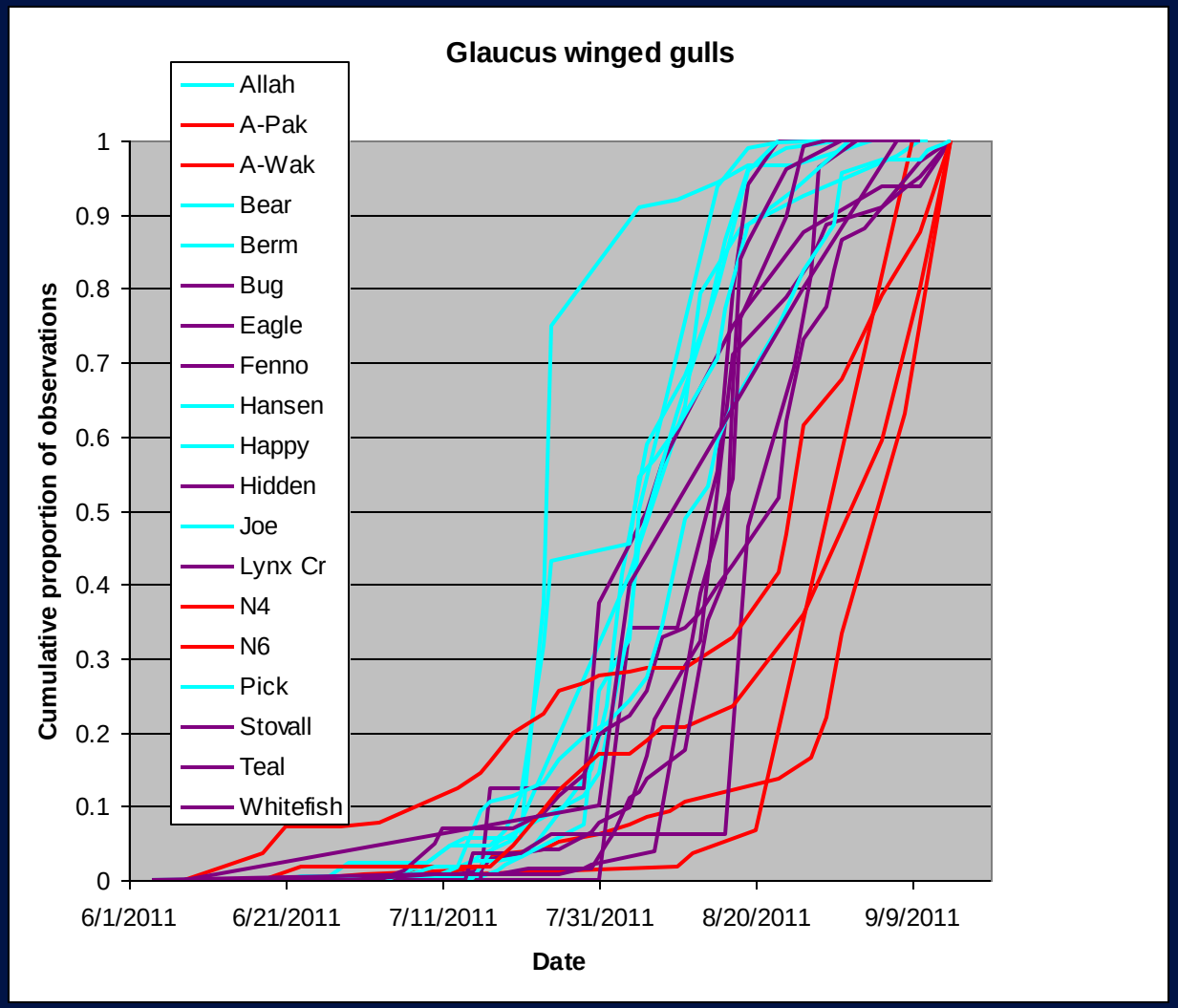


Schindler et al. 2010 *Nature*

Consumers exploit the shifting mosaic of salmon resources



Consumers exploit the shifting mosaic of salmon resources



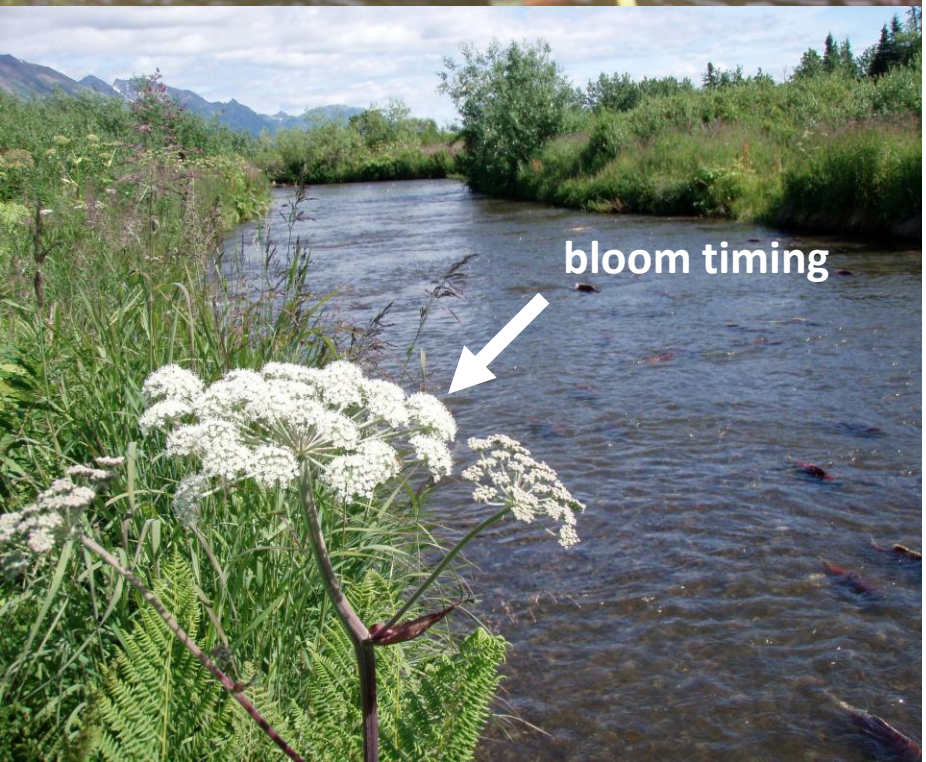
Aquatic – terrestrial connections

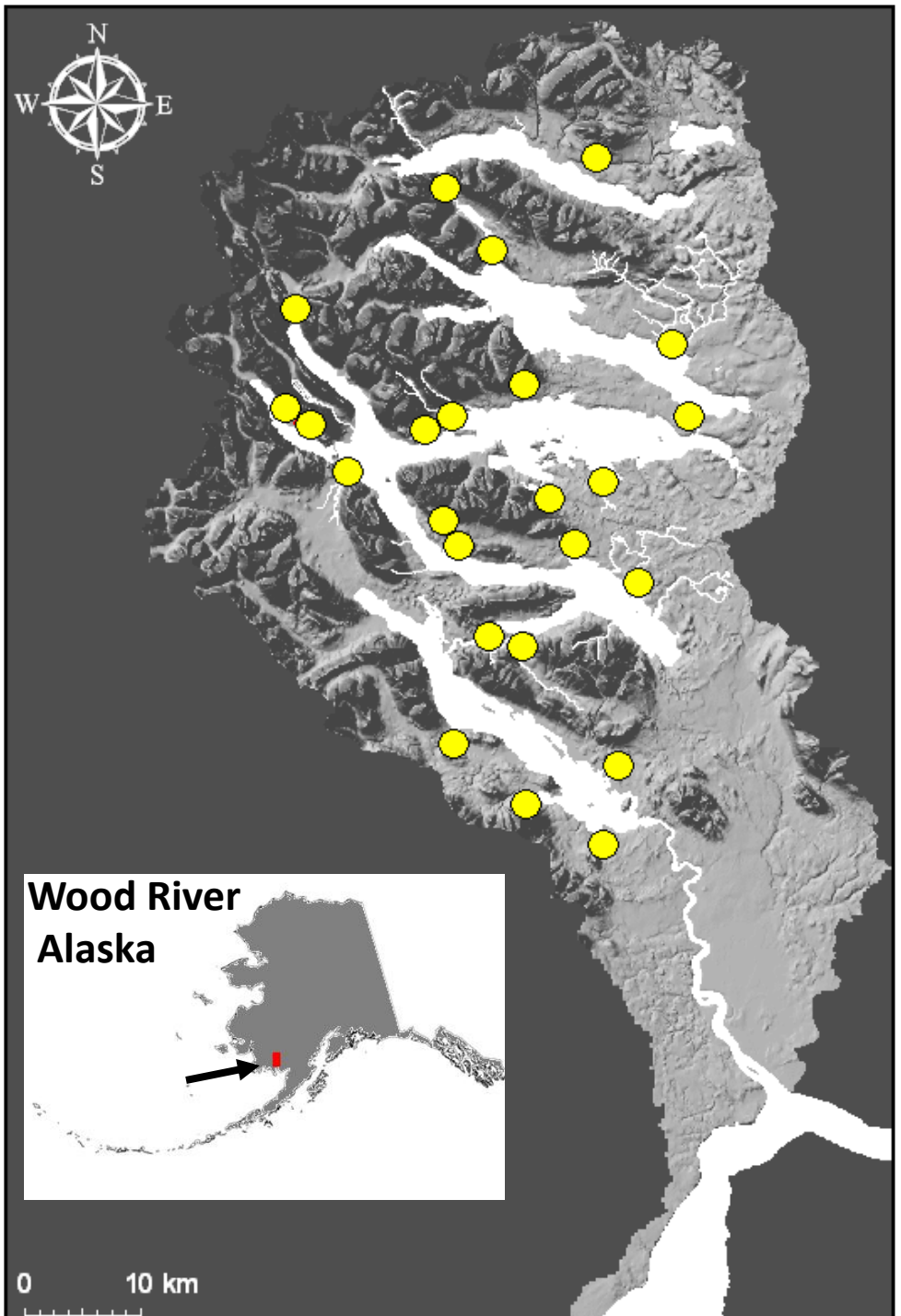
Heterogeneous landscape

aquatic-terrestrial connections

salmon

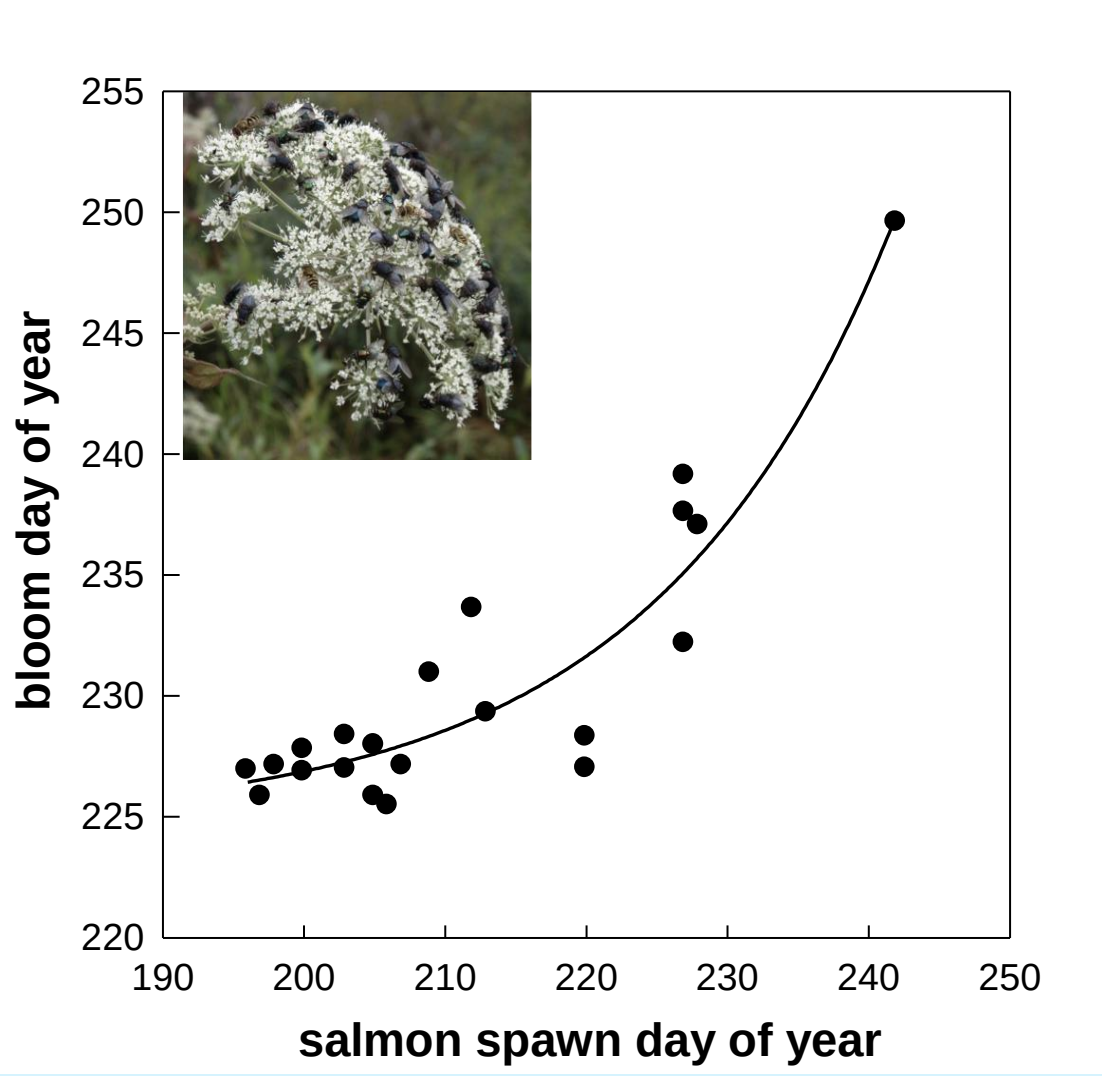

spawn timing


bloom timing


N
W
E
S
Wood River
Alaska
0
10 km

Link between aquatic and riparian biodiversity

Salmon spawn timing propagates to bloom timing of riparian plants



Lisi and Schindler, *Ecosphere*, 2011

Hydrologic diversity supports biodiversity in aquatic and terrestrial habitats

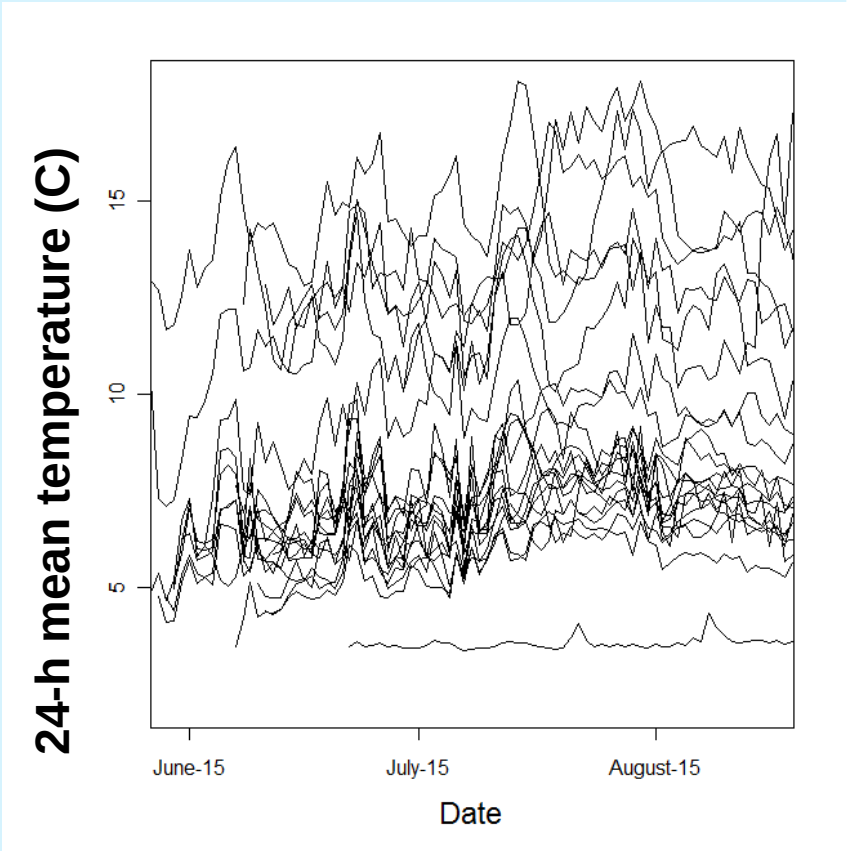
Heterogeneous landscape

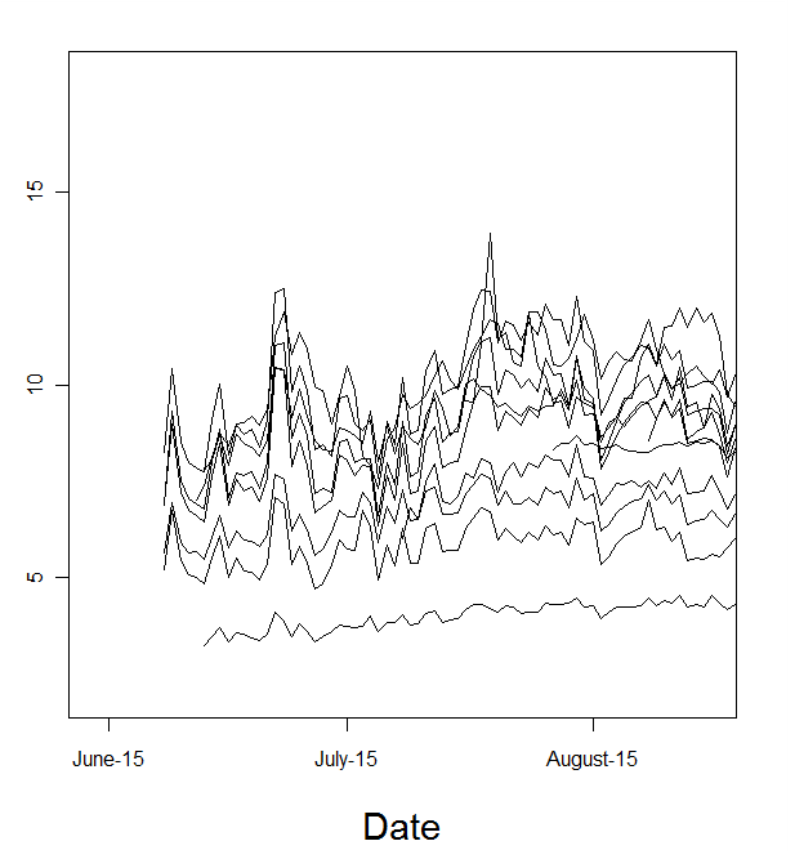
regional climate ->
precipitation ->
geomorphology ->
stream hydrology ->
animal life-history->
plant life-history

salmon

aquatic terrestrial connections

Temperature variation in the Wood River system



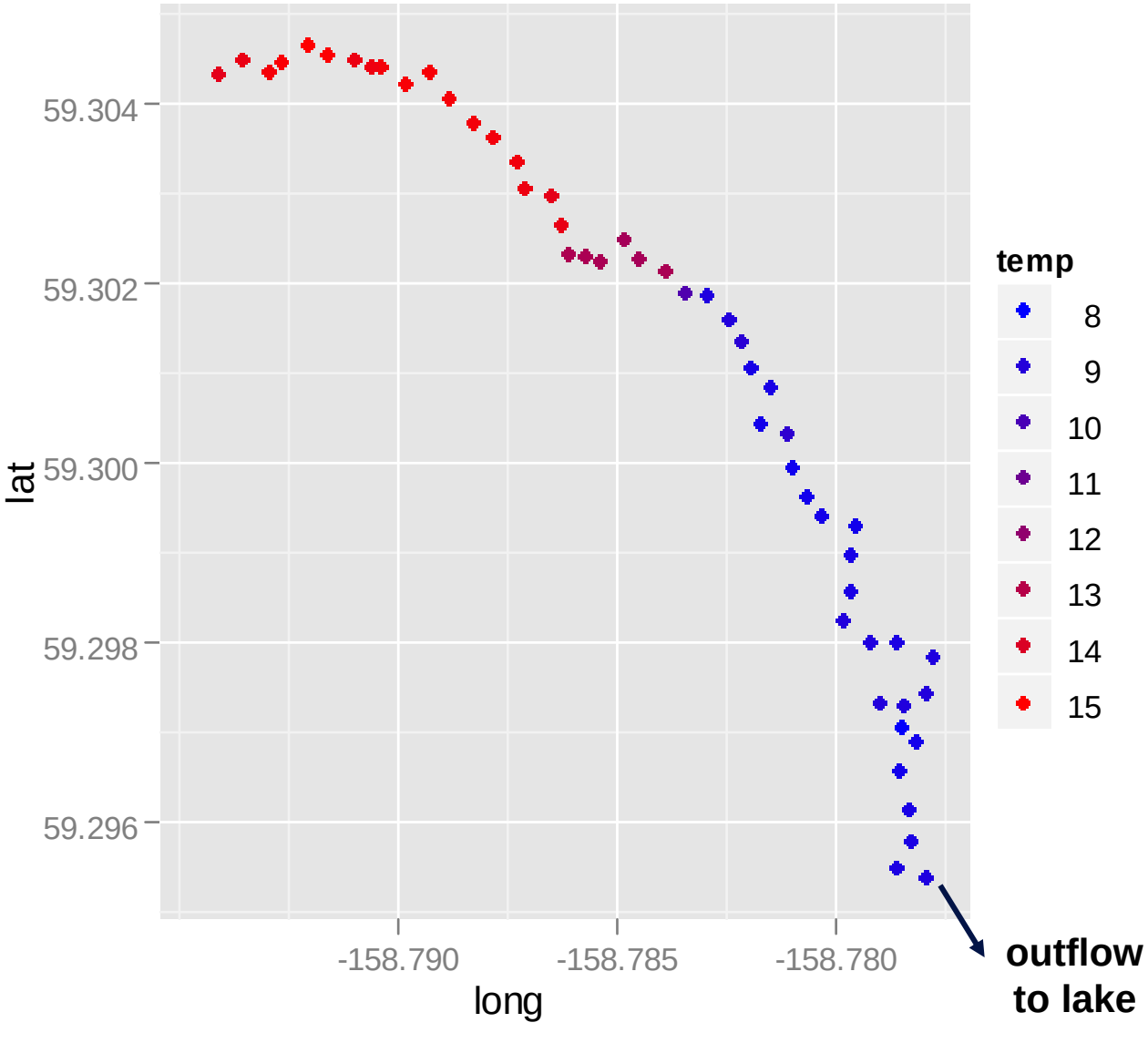


Among-stream variation

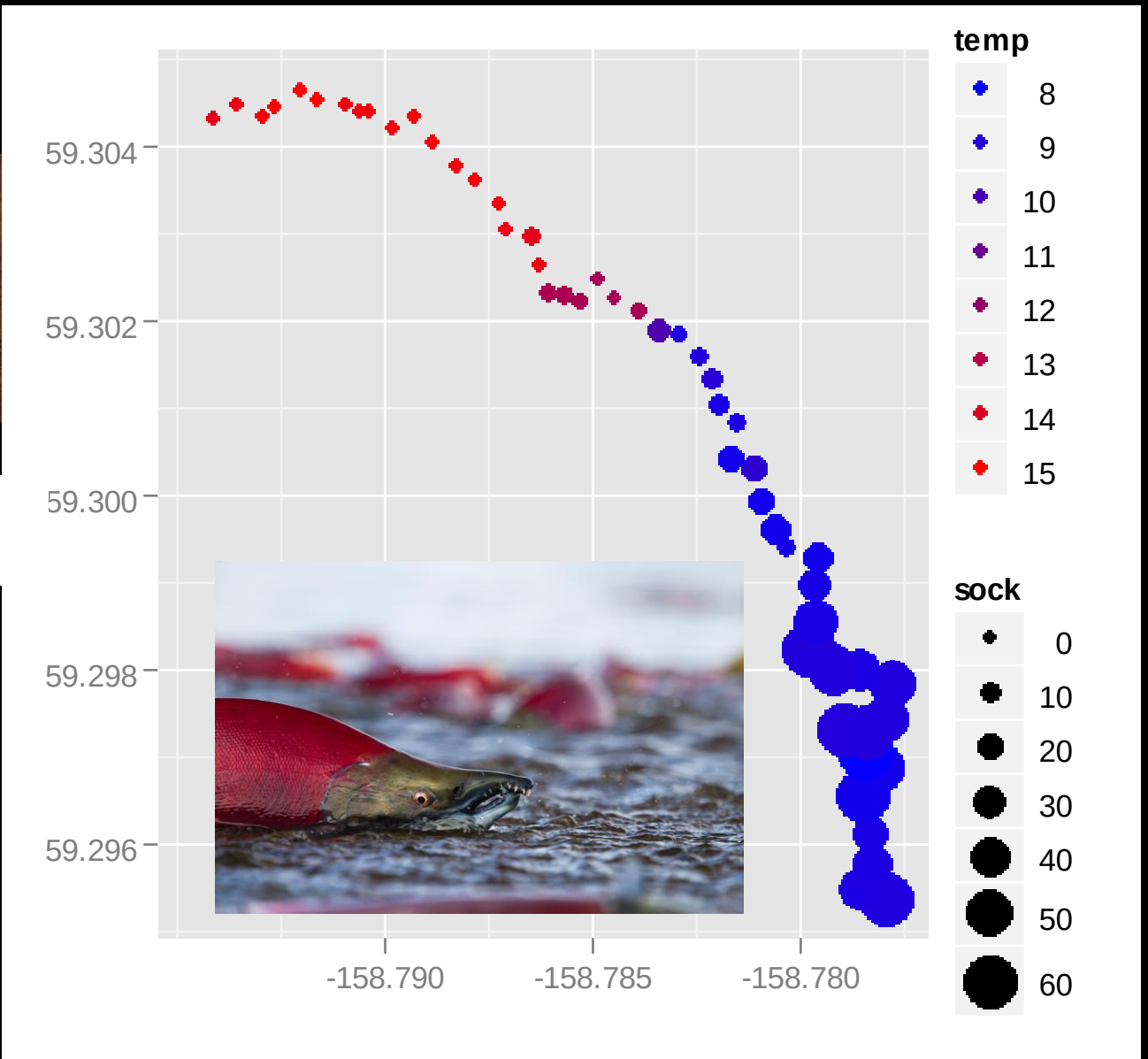
Within-stream variation

Jonny Armstrong

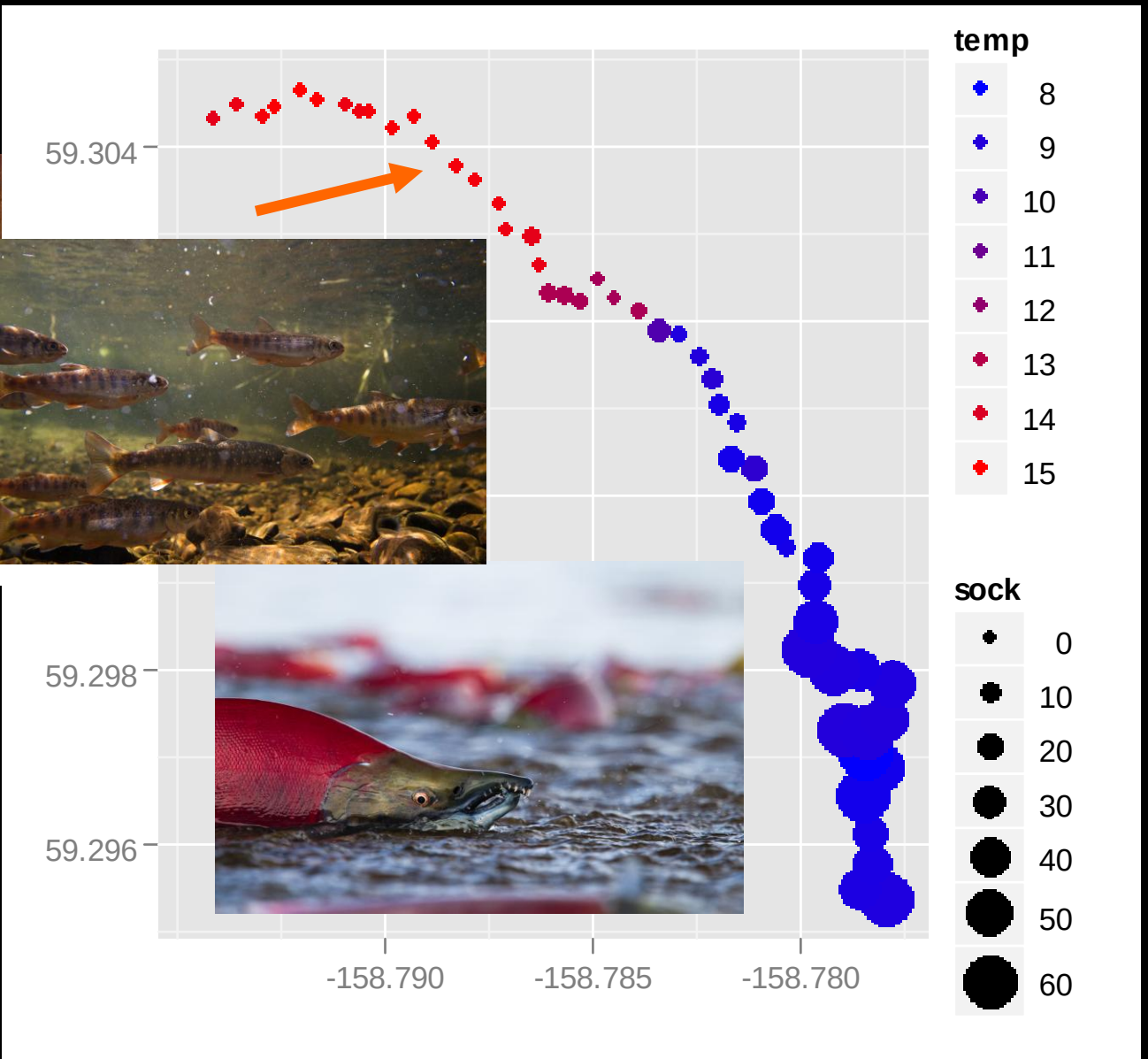
Jonny Armstrong



- **Bear Creek, 3-km long, rearing habitat for coho salmon**



- **Bear Creek, 2.5 km long, rearing habitat for coho salmon**
- **Counter-gradient of food and water temperature**



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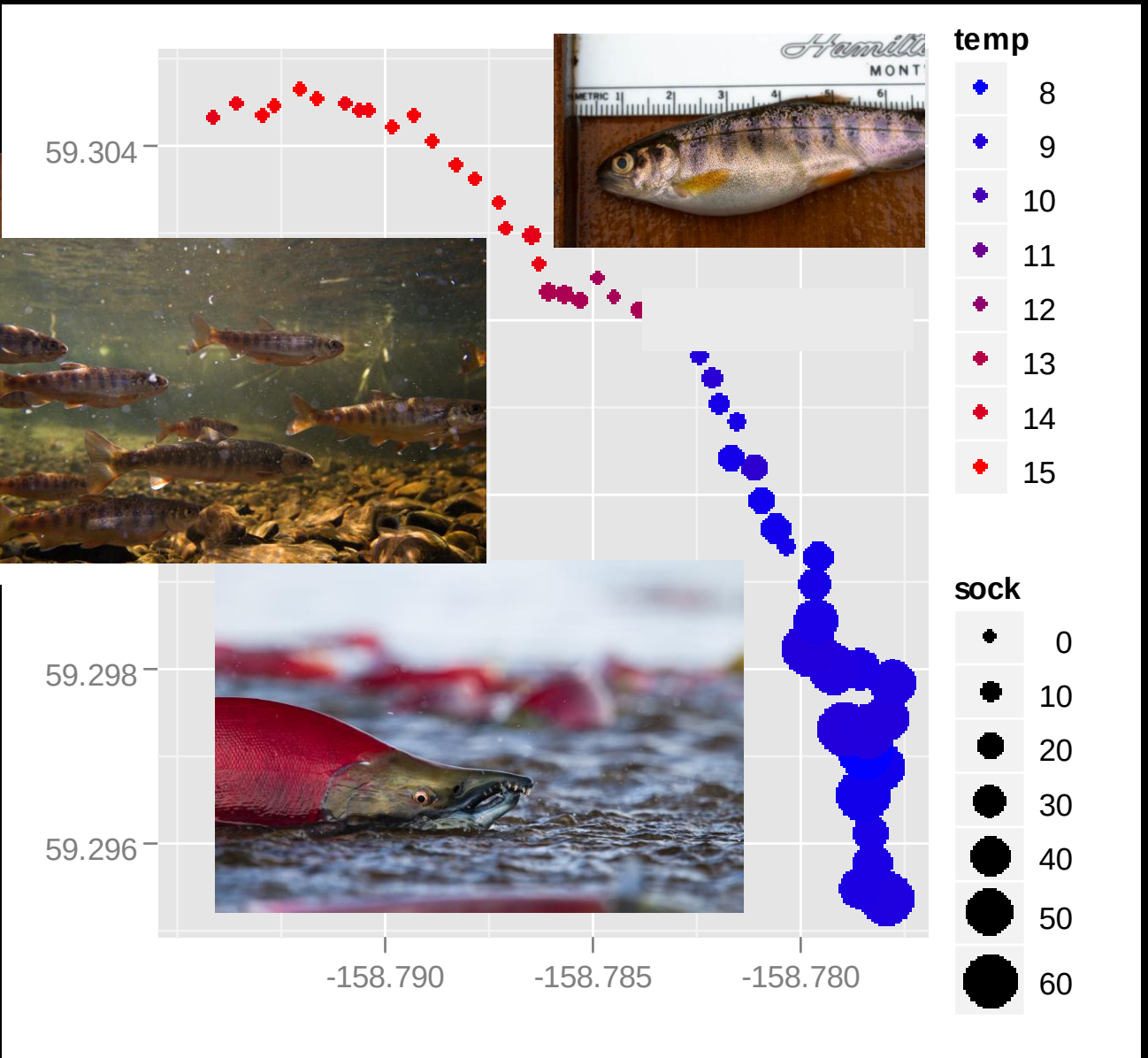

- **Bear Creek, 2.5 km long, rearing habitat for coho salmon**
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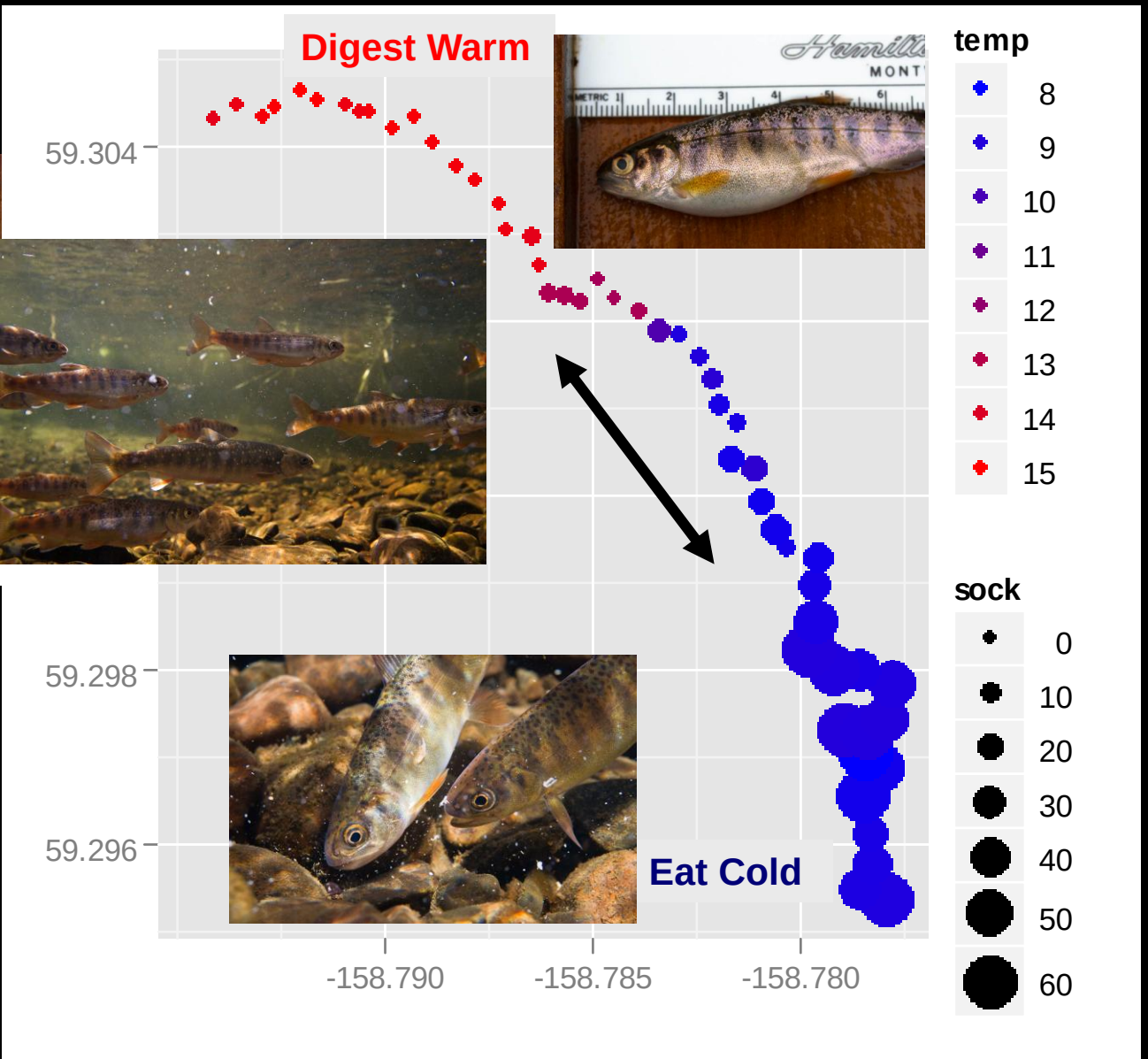
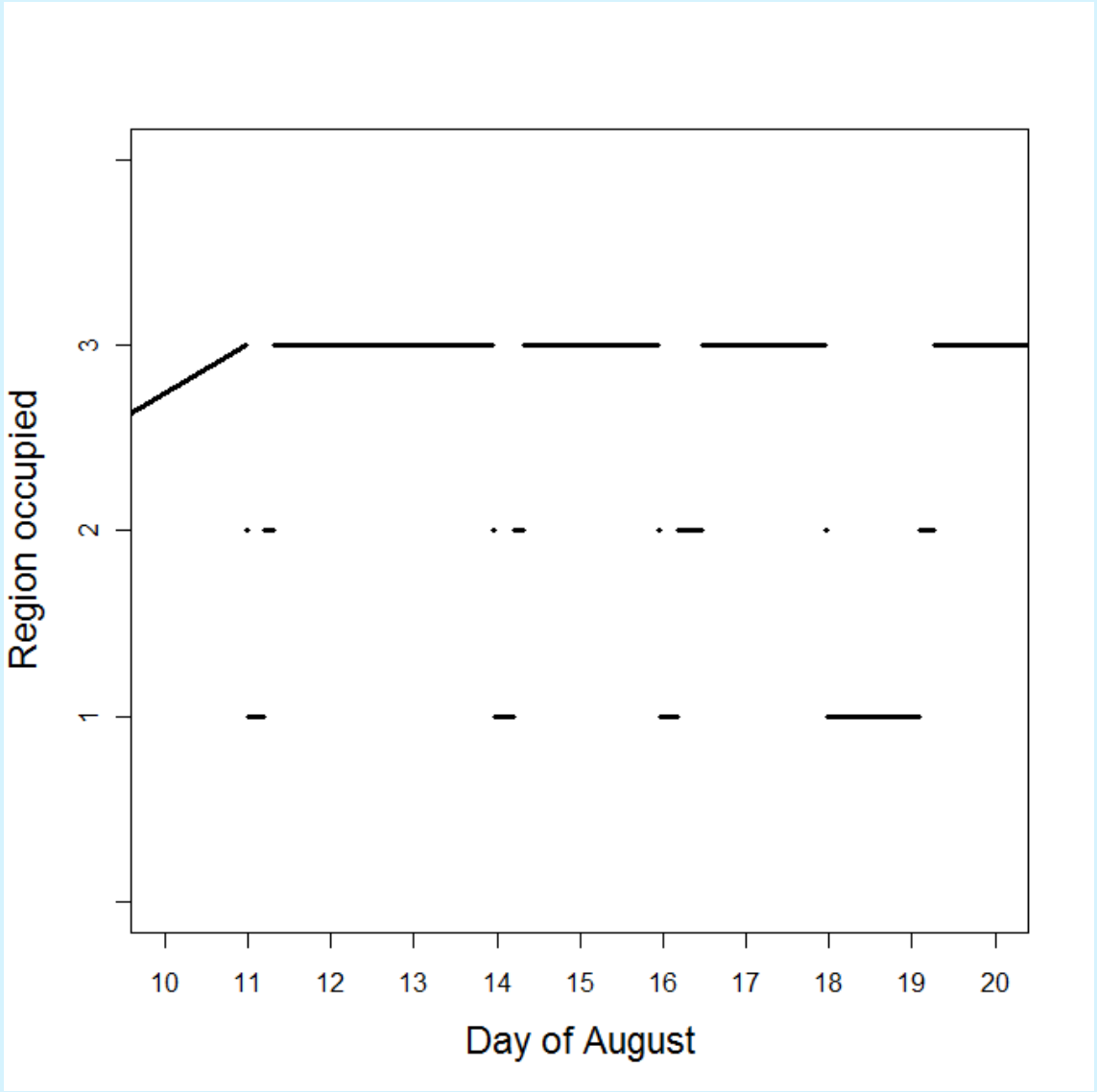
Behavioral Thermoregulation

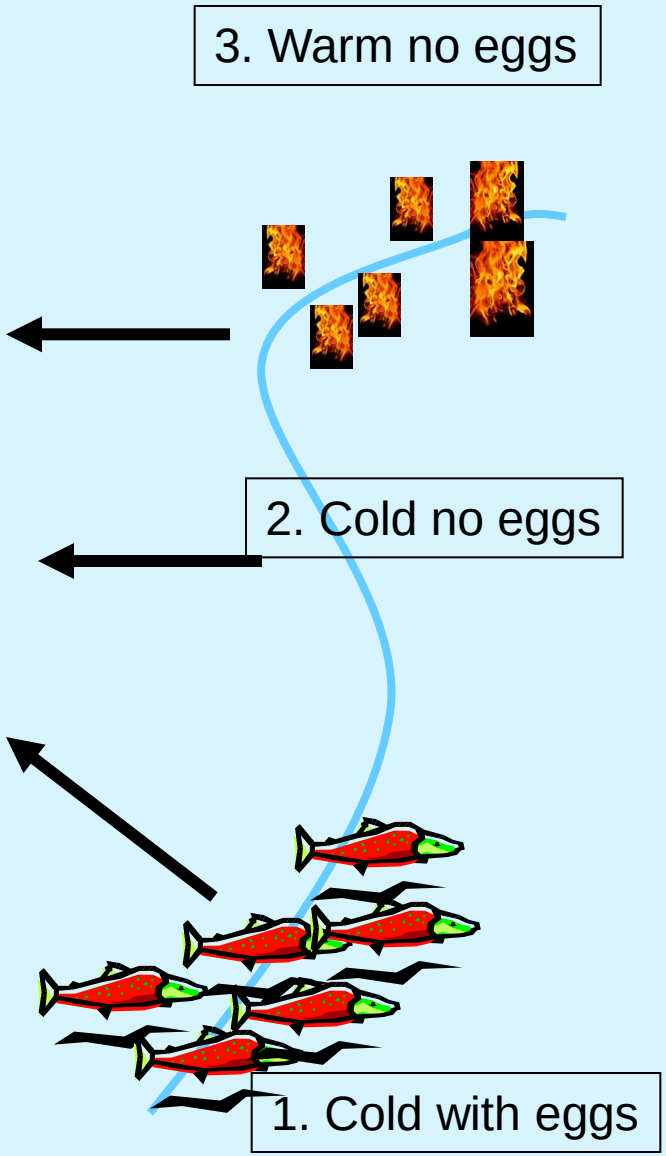


- Bear Creek, 2.5 km long, rearing habitat for coho salmon
- Counter-gradient of food and water temperature

Juvenile coho salmon movements

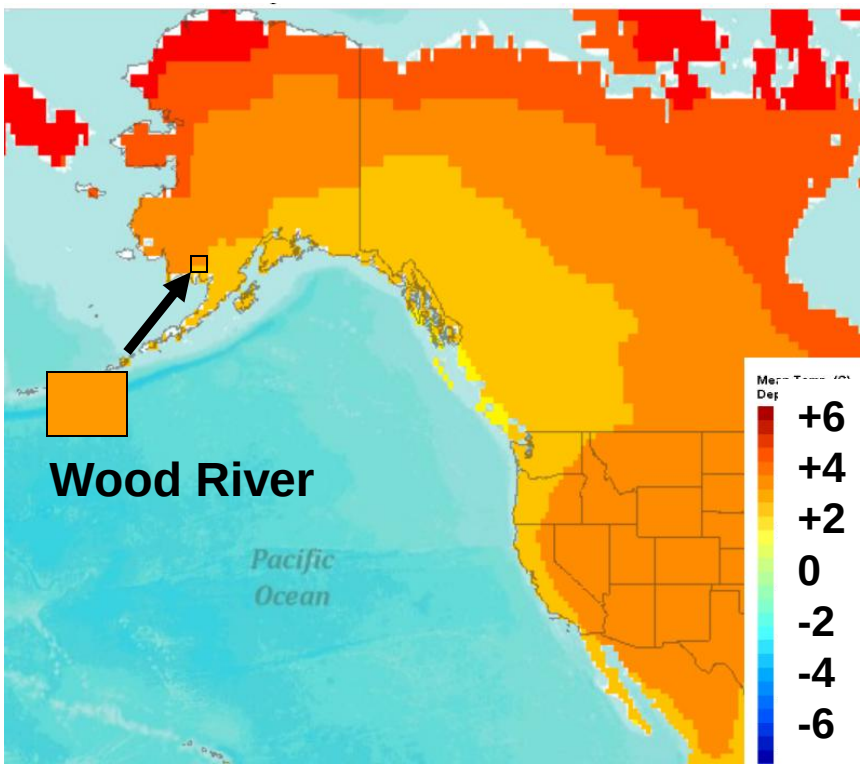
Juvenile coho exploit temperature variation to enhance growth

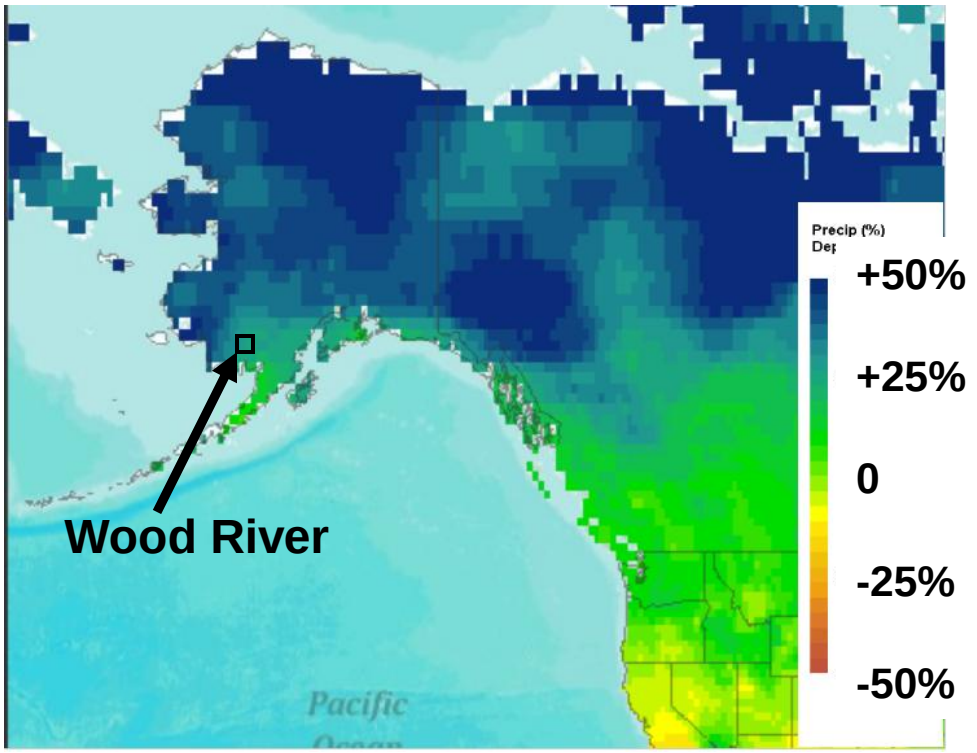




Jonny Armstrong

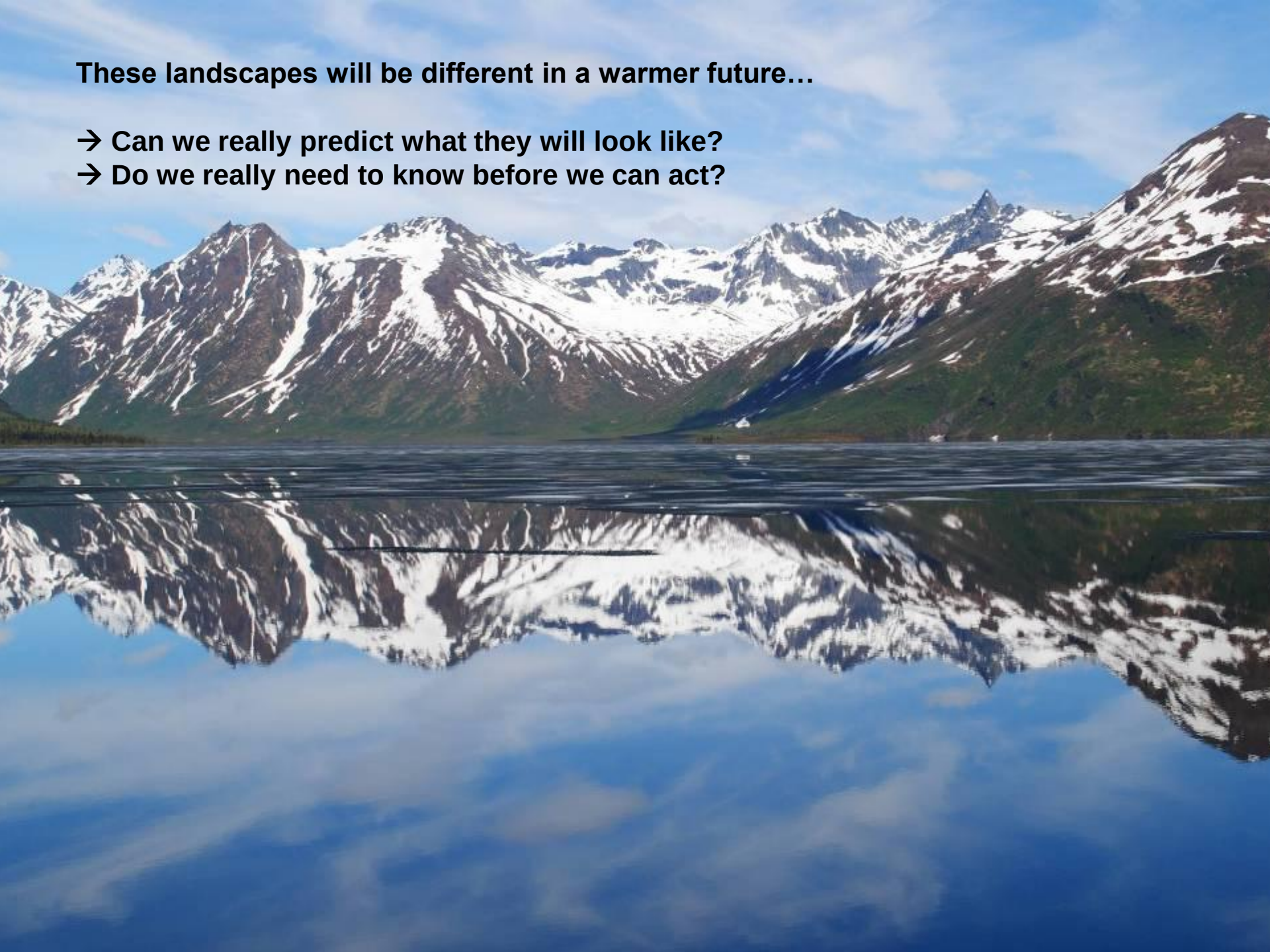
Coastal watersheds are predicted to have
2 to 3 degrees warmer air and 25 to 50% more precipitation





Predicted air and precipitation departures from today in 2079-2099 with continued rate of anthropogenic CO_2.

Maurer, et al (2007), Eos Trans. AGU, 88(47), 504



These landscapes will be different in a warmer future…

→ Can we really predict what they will look like?
→ Do we really need to know before we can act?

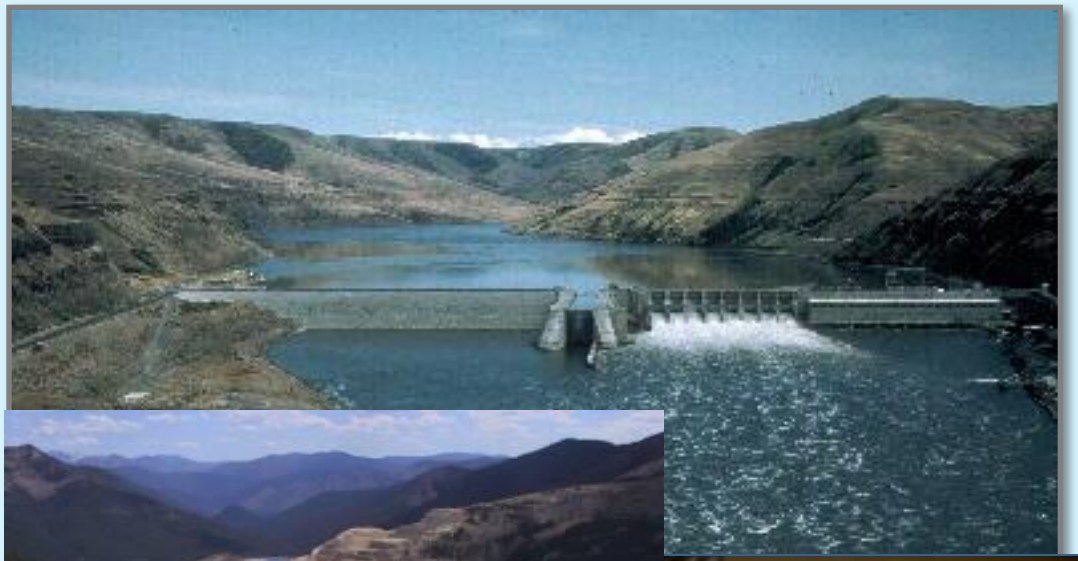

Maintaining diversity in landscapes is a tangible way to manage the risks of ongoing climate warming

Disturbances maintain diverse and productive habitats

Stability and productivity derive from diverse and changing habitat

Bristol Bay, Alaska

Pacific Northwest



Thanks to: National Science Foundation, Gordon and Betty Moore Foundation, Alaska Salmon Processors, Bristol Bay RSDA, Alaska Dept. of Fish & Game, US Fish & Wildlife Service (LCC), Wood-Tikchik SP, Katmai NPP

University of Washington

NOAA